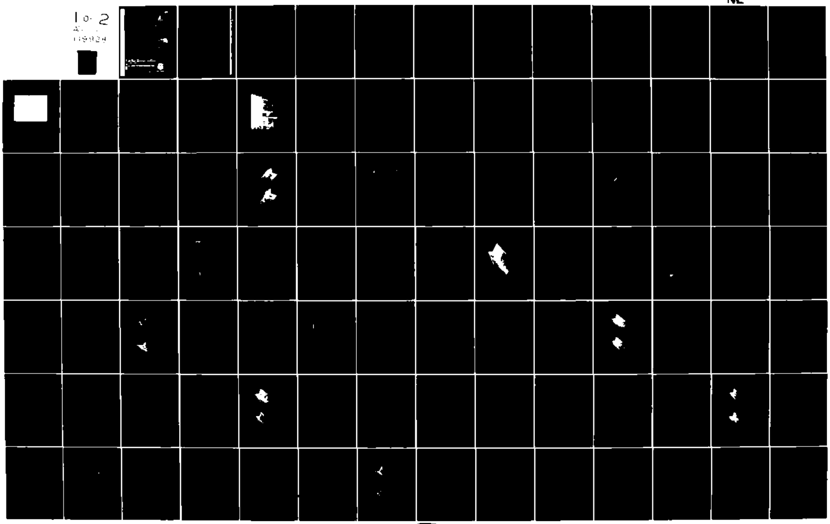
AD-A119 928 AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA F/G 4/2
MICROPHYSICAL PROPERTIES OF FOG AT OTIS AIR FORCE BASE.(U)
JAN 82 B A KUNKEL
UNCLASSIFIED AFGL-TR-82-0026 NL



AFGL-TR-[illegible]
ENVIRONMENTAL RESEARCH PAPERS, NO. [illegible]

Microphysical Properties of Fog at Otis AFB

BRUCE A. KUNKEL

[illegible] January [illegible]

This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

Alva T. Stair, Jr.

DR. ALVA T. STAIR, Jr
Chief Scientist

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-82-0026	2. GOVT ACCESSION NO. AD-A119928	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MICROPHYSICAL PROPERTIES OF FOG AT OTIS AFB		5. TYPE OF REPORT & PERIOD COVERED Scientific. Final.
		6. PERFORMING ORG. REPORT NUMBER ERP, NO. 767
7. AUTHOR(s) Bruce A. Kunkel		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Geophysics Laboratory (LYT) Hanscom AFB Massachusetts 01731		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 66701009
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory (LYT) Hanscom AFB Massachusetts 01731		12. REPORT DATE 26 January 1982
		13. NUMBER OF PAGES 113
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Fog; Microphysics; Spectrometer; Drop size distributions		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of an effort to develop improved techniques for predicting advection fog, fog droplet spectra data were collected during several advection fog episodes ~~at the AFGL Weather Test Facility~~ at Otis AFB. The data were collected with two PMS forward scatter probes (FSSP-100) and two optical array probes (OAP-200X). These two probes cover the ranges from 0.5- to 47-μm and 20- to 300-μm diameter, respectively. The probes were mounted at 5 m and 30 m above the ground. Drop size data were obtained in nine fogs over a total period of 70 h. Other data that were collected continuously during

DD FORM 1 JAN 73 1473

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. Abstract (Continued)

the fog episodes include extinction coefficient, temperature, dew point, wind direction, and speed at the 5-, 15-, 30-, 45-, and 60-m levels. The droplet data show three basic types of spectra, all of which have a high droplet count below 2.5-μm diameter. Some spectra show as many as three modes while others show no modes within the size range of the instruments. The shape of the droplet spectra and the number concentration vary considerably from one fog to another and during a fog episode. The total droplet concentration appears to be a function, primarily, of the past trajectory of the air mass; lower counts being observed in air masses with long over water trajectories. The drop-size data were used to parameterize the extinction coefficient and the mean droplet terminal velocity in terms of liquid water content and droplet concentration for use in numerical prediction models. The new parameterizations will result in the prediction of lower liquid-water contents and higher visibilities than with previous parameterization used in fog prediction models.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Preface

The author wishes to thank Mr. Stuart Sheets for installing and maintaining the PMS spectrometer system. Because of his dedicated efforts, the percentage of downtime was kept to a minimum and a high degree of confidence can be placed on the data. Thanks also go to Mrs. Joan Ward for her efforts in programming the plotting routines for some of the figures. The author wishes to acknowledge the assistance of Mrs. Helen Connell in typing the manuscript.

Contents

1. INTRODUCTION	11
2. SITE AND INSTRUMENTATION	12
3. DATA	18
4. MICROPHYSICAL DATA ANALYSIS	19
4.1 Average Droplet Spectra	19
4.2 Height Variation	24
4.3 Temporal Variation	28
5. MODEL APPLICATIONS	30
5.1 Mean Terminal Velocity	30
5.2 Extinction Coefficient/Liquid Water Content Relationship	33
REFERENCES	39
APPENDIX A: METEOROLOGICAL DATA	41

Illustrations

1. Location of the AFGL Weather Test Facility	12
2. Aerial View of the AFGL Weather Test Facility	13
3. Diagram of the FSSP Optical System	14
4. Diagram of the OAP Optical System	15

Illustrations

5. Photograph of the OAP (Upper) and FSSP (Lower) Mounted Near the 5-m Level on a Tower at the AFGL Weather Test Facility 17

6. Three Types of Drop Size Spectra Observed in Advection Fogs at the WTF at Otis AFB 19

7. The Distribution of Liquid Water for the Three Spectra Shown in Figure 6 21

8. The Distribution of Extinction for the Three Spectra Shown in Figure 6 21

9. The Cumulative Frequency Distribution of Number Concentration, Liquid Water Content, and Extinction Coefficient for the Three Spectra Shown in Figure 6 22

10. Examples of Simultaneous Drop Size Distributions Obtained With the FSSP (0.5-47 μm) and OAP (34-300 μm) 23

11. The Percentage of Time That the Liquid Water Content at 5 m and 30 m Above the Ground is Below a Given Value 26

12. A Time Sequence of Droplet Spectra at the 5-m and 30-m Levels During an Advection Fog on the Night of 10-11 July 1980 27

13. A Linear Regression Line Between the Slope of the Distribution Between 0.5-1.0 μm and 1.0-1.5 μm Size Ranges at 5 m and the Total Concentration of Particles at 30 m Relative to the Total Concentration at 5 m 28

14. The Temporal Variation of the Microphysical Parameters During a Fog on the Night of 10-11 July 1980 29

15. A Three-Dimensional Time Plot of the Droplet Spectra at the 5-m and 30-m Levels for a Fog on the Night of 10-11 July 1980 31

16. Linear Regression Lines Relating the Mean Droplet Terminal Velocity With Various Microphysical Parameters 33

17. A Comparison of the Mean Terminal Velocity/Liquid Water Content Relationship Derived From the Otis Data With Those Derived by Brown[10] and Rogers[9] 34

18. The Relationships Between Extinction Coefficient and Liquid Water Content for Eight Advection Fog Cases 36

19. The Mean Relationship Between Extinction Coefficient and Liquid Water Content Derived From Data Taken at the 5- and 30-m Levels 37

20. A Comparison of Various Relationships Between Extinction Coefficient and Liquid Water Content 38

A1. Surface Weather Observations Taken at the FAA Tower at Otis AFB 43

A2. Surface Weather Map for 0800 EDT on 27 June 1980 44

A3. Chatham Radiosonde Soundings Before and After the Fog Episode 45

A4. The Temporal Variability of the Fog Microphysical Parameters 46

A5. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level 47

A6. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m Level 48

A7. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level 49

A8. Surface Weather Observations Taken at the FAA Tower at Otis AFB 51

A9. Surface Weather Map for 0800 EDT on 3 July 1980 52

A10. Chatham Radiosonde Soundings Before and After the Fog Episode 53

A11. The Temporal Variability of the Fog Microphysical Parameters 54

A12. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels 55

A13. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels 56

A14. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels 57

A15. Surface Weather Observations Taken at the FAA Tower at Otis AFB 59

A16. Surface Weather Map for 0800 EDT on 4 July 1980 60

A17. Chatham Radiosonde Soundings Before and After the Fog Episode 61

A18. The Temporal Variability of the Fog Microphysical Parameters 62

A19. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level 63

A20. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m Level 64

A21. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level 65

A22. Surface Weather Observations Taken at the FAA Tower at Otis AFB 67

A23. Surface Weather Map for 0800 EDT on 11 July 1980 68

A24. Chatham Radiosonde Soundings Before and After the Fog Episode 69

A25. The Temporal Variability of the Fog Microphysical Parameters 70

A26. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels 71

A27. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels 72

A28.	Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	73
A29.	Surface Weather Observations Taken at the FAA Tower at Otis AFB	75
A30.	Surface Weather Map for 0800 EDT on 12 July 1980	76
A31.	Chatham Radiosonde Sounding Before and After the Fog Episode	77
A32.	The Temporal Variability of the Fog Microphysical Parameters	78
A33.	Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	79
A34.	Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	80
A35.	Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	81
A36.	Surface Weather Observations Taken at the FAA Tower at Otis AFB	83
A37.	Surface Weather Map for 0800 EDT on 18 July 1980	84
A38.	Chatham Radiosonde Soundings Before and After the Fog Episode	85
A39.	The Temporal Variability of the Fog Microphysical Parameters	86
A40.	Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	87
A41.	Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	88
A42.	Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	89
A43.	Surface Weather Observations Taken at the FAA Tower at Otis AFB	91
A44.	Surface Weather Map for 0800 EDT on 29 July 1980	92
A45.	Chatham Radiosonde Soundings Before and After the Fog Episode	93
A46.	The Temporal Variability of the Fog Microphysical Parameters	94
A47.	Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	95
A48.	Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	96
A49.	Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels	97
A50.	Surface Weather Observations Taken at the FAA Tower at Otis AFB	99

Illustrations

A51. Surface Weather Map for 0800 EDT on 30 July 1980 — 100

A52. Chatham Radiosonde Soundings Before and After the Fog Episode — 101

A53. The Temporal Variability of the Fog Microphysical Parameters — 102

A54. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 103

A55. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 104

A56. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 105

A57. Surface Weather Observations Taken at the FAA Tower at Otis AFB — 107

A58. Surface Weather Map for 0800 EDT on 6 August 1980 — 108

A59. Chatham Radiosonde Soundings Before and After the Fog Episode — 109

A60. The Temporal Variability of the Fog Microphysical Parameters — 110

A61. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 111

A62. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 112

A63. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels — 113

Tables

1. Size Range Parameters for FSSP-100 Cloud Droplet Probe — 15
2. Operating Times for PMS Spectrometer System — 18
3. The Mean Microphysical Parameters of the Fogs Observed at the WTF at Otis AFB, Massachusetts — 25

Microphysical Properties of Fog at Otis AFB

1. INTRODUCTION

The AFGL has an ongoing project to develop techniques for the short-range prediction of the occurrence and dissipation of fog, as well as the visibility during fog. To achieve this goal, field measurements and numerical modeling studies are being conducted to learn more about the structure and evolutionary processes that take place during the fog life cycle.

This report focuses on one aspect of this study, that is, the collection and evaluation of microphysical data during advection fog episodes at the AFGL Weather Test Facility (WTF) at Otis AFB, Mass. The intent of this data collection effort is to (1) learn more about the physical structure and processes that take place during the fog life cycle, (2) develop more accurate parameterization of visibility and gravitational settling of fog droplets in terms of the microphysical parameters, and (3) provide an extensive data base that can be used as an aid in developing and evaluating fog forecast models. These data can also be used in studies relating to electromagnetic propagation through foggy environments and to development of new fog modification or prevention techniques.

Instrumentation that provide continuous drop-size measurements over a broad drop-size range with rapid data reduction capability have existed only over the past few years. Most previous data were collected by the impaction technique,

(Received for publication 13 January 1982)

which required many hours of tedious labor to reduce a limited amount of data. Also, most impaction techniques are not reliable below about 6-μm diameter because of collection efficiency problems.

In this study, fog drop-size data were obtained with a PMS forward scatter and optical array spectrometer system. The data were acquired during fog episodes in 1980 at the WTF. Section 2 describes the field site and instrumentation. Section 3 describes the type and quantity of data collected during the seven-week field program. The types of droplet spectra and their temporal and spatial variations are discussed in Section 4. Based on the droplet spectra data, new parameterization of extinction coefficients and gravitational settling of fog droplets in terms of liquid water content and droplet concentration are presented in Section 5. The meteorological and microphysical data for the various fog cases are presented in the Appendix.

2. SITE AND INSTRUMENTATION

The measurement program took place at the WTF at Otis AFB, Mass., located on Cape Cod about 12-km inland from the South Shore (see Figure 1).

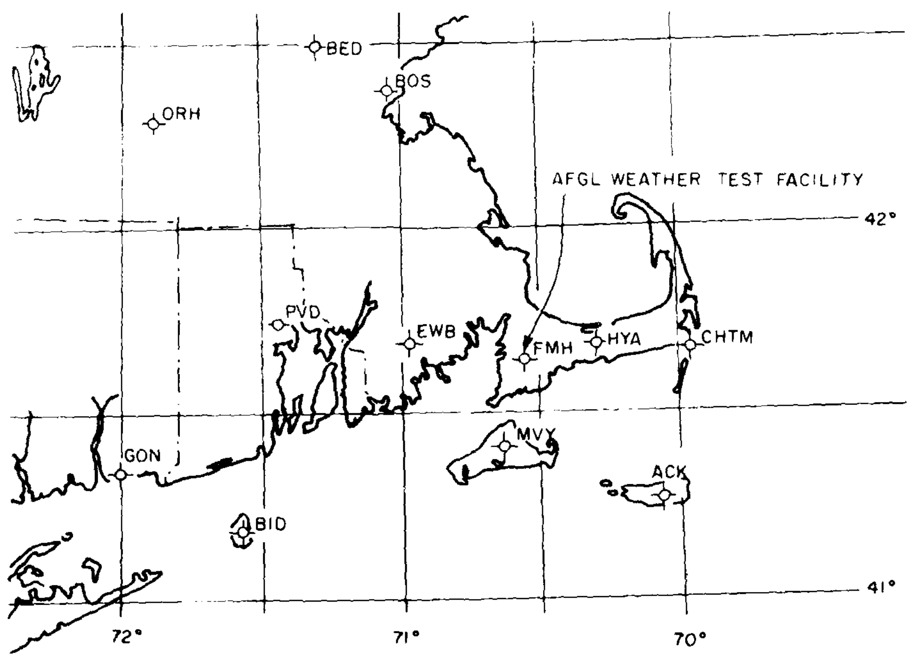


Figure 1. Location of the AFGL Weather Test Facility

The site covers a rather broad, flat, open area as shown in Figure 2. The site is about 38-m above sea level.

Figure 2. Aerial View of the AFGL Weather Test Facility

The purpose of this facility is twofold: to evaluate new meteorological sensors and automated data systems, and to collect data for use in various short-range forecast studies conducted at AFGL.

The facility has an array of meteorological sensors located near the ground and on various 60-m and 30-m towers. Among the more important instruments are EG&G temperature-dewpoint sensors, EG&G forward scatter meters, rotating beam ceilometers, Climatronic wind sensors, an Aerovironment monostatic acoustic sounder, and a bistatic acoustic sounder for obtaining winds up to a height of 90 m.

The drop-size instrumentation used in this study included two Particle Measuring Systems (PMS) Forward Scatter Spectrometer Probes (FSSP-100) and two PMS Optical Array Spectrometer Probes (OAP-200X) purchased in 1979. The data from the four probes were fed into a data acquisition system (DAS-64) and recorded on magnetic tape.

The FSSP-100 works on the principle that the magnitude of light scattered in the forward direction by a droplet is directly related to droplet size. As droplets flow through a volume illuminated by a 5 mW He-Ne laser, the scattered energy is relayed through a right angle prism and an interference filter and collected by the scattering photodetector module (Figure 3). An aspirator, mounted on the probe, produces a flow rate of 26 m/sec through the sampling area to ensure the measurement of representative samples and a constant sample volume. There are four overlapping size ranges, with each size range divided into 15 linear-size intervals (see Table 1). The DAS-64 accumulates the droplet count in the 15 size bins of a given range setting over a prescribed time period and then transfers the information to magnetic tape. The system was operated so that it sequentially stepped through the four size ranges every 50 sec, thus providing a complete spectrum from 0.5- to 47-μm diameter.

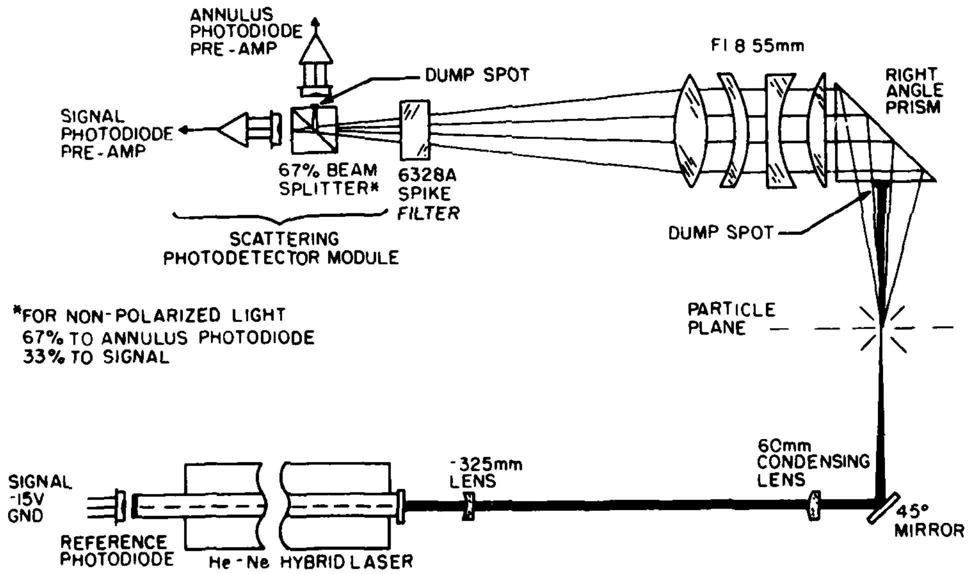


Figure 3. Diagram of the FSSP Optical System

Table 1. Size Range Parameters for FSSP-100 Cloud Droplet Probe

Range Setting	Size Range (μm)	Size Interval (μm)	Portion of Range Used (μm)	No. of Intervals
0	2-47	3	26-47	7
1	2-32	2	14-26	6
2	1-16	1	7-14	7
3	0.5-8	0.5	0.5-7	13

Data were accumulated in each size range for 10 sec. The exception was in the large droplet size range (2 to 47 μm) where data were accumulated for 20 sec to allow for a more representative sampling of the upper end of the spectrum where droplet counts were relatively low. The sample volume for each 50-sec period was about 90 cm^3 for each size interval up to 26-μm diameter and 180 cm^3 for each size interval greater than 26 μm. A total of 33 nonoverlapping size bins from the four size ranges were used in calculating the droplet spectra and microphysical data.

In the optical array spectrometer (OAP-200X), particles are sized using a linear array of photodiodes to sense the shadowing of array elements by particles passing through its field-of-view. Particles are illuminated by a 2 mW He-Ne laser and imaged as shadowgraphs onto the photodiode array (Figure 4).

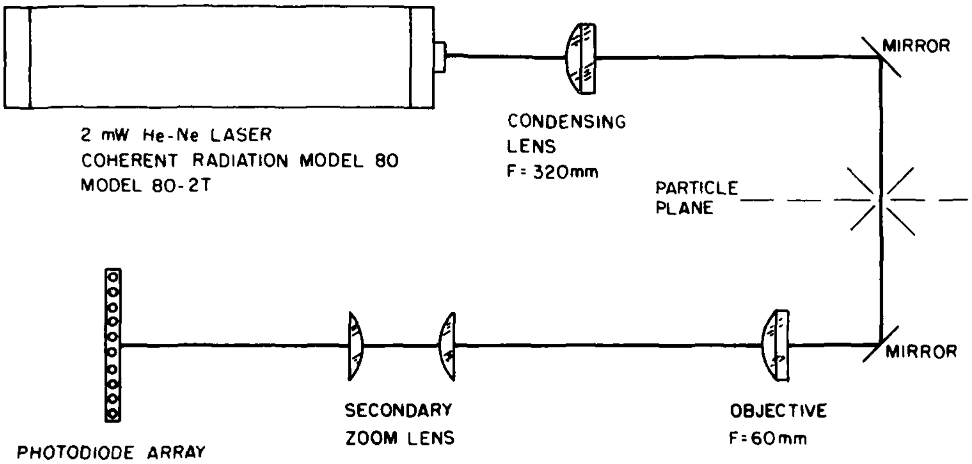


Figure 4. Diagram of the OAP Optical System

If the shadowing of each photodiode element is of sufficient magnitude, a flip-flop memory element is set. The particle size results from a determination of the number of elements set by a particle's passage, the size of each array element, and the magnification of the optical system. The system contains 24 active photodiode elements and is capable of sizing particles into 15-linear size bins in the 20- to 300-μm diameter range. In order to obtain a representative sample and a constant sample volume, an aspirator, producing a flow rate of 13.4 m/sec through the sampling area, is mounted on the probe. The DAS-64 accumulated the droplet count in the 15 size bins over a 1-sec time interval and recorded the data on magnetic tape. The sample volume varies with droplet size and ranges from 2.3 cm^3/sec at 20 μm to a maximum of 245 cm^3/sec at 160 μm to 130 cm^3/sec at 300 μm.

Figure 5 shows the FSSP-100 and the OAP-200X mounted near the 5-m level of the 60-m tower. Also shown on each probe is the aspirator's horn, which helps to prevent size selection sorting of the particle sample. The FSSP is mounted on a swivel that allows the probe to continuously face into the wind. The OAP can be manually turned into the wind.

Before and during the measurement program a number of comparative tests were conducted between the probes and with the Calspan droplet sampler. The result of these comparisons is described by Kunkel.[1] In general, the agreements were very good, except that the probes detected many more droplets below 8-μm diameter than did the Calspan droplet sampler. Apparently, because of low collection efficiencies below 8 μm, the sampler, an impaction type device, does not detect the smaller droplets. In the denser fogs, the extinction coefficients calculated from the drop-size distributions were generally higher than the extinction coefficients measured by the EG&G forward scatter meter. This means that the measured concentrations and/or sizes were higher than the actual, assuming that the measured extinction coefficients were correct. Vali et al,[2] found that the FSSP measured broader droplet spectra than the University of Wyoming cloud gun, thus resulting in an overestimate of the liquid water content and, consequently, extinction coefficient. They attributed this broadening to the nonuniformity of the laser beam. The values presented in this report are the values actually measured.

---

1. Kunkel, B.A. (1981) Comparison of Fog Drop Size Spectra Measured by Light Scattering and Impaction Techniques, AFGL-TR-81-0049, ADA 100252.
2. Vali, G., Politovich, M.K., and Baumgardner, D.G. (1981) Conduct of Cloud Spectra Measurements, AFGL-TR-81-0122, ADA 102944.

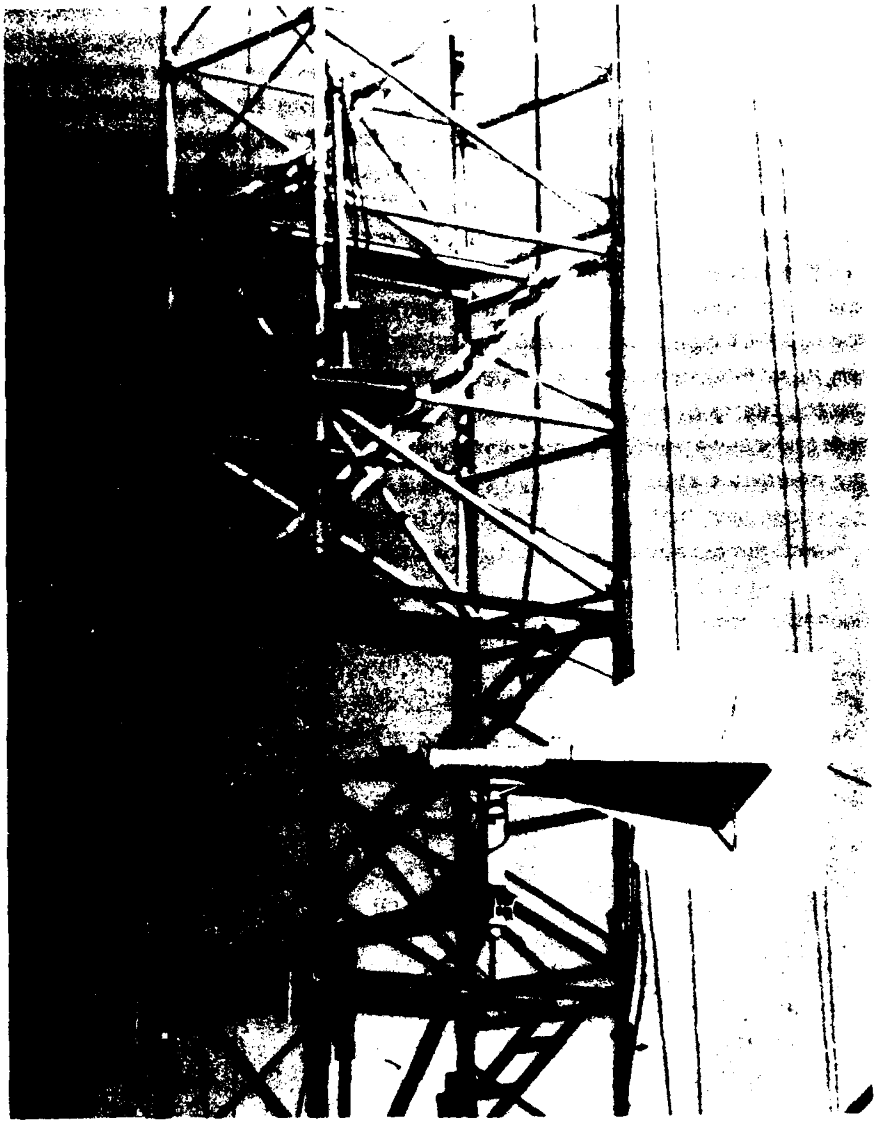


Figure 5. Photograph of the OAP (Upper) and FSSP (Lower) Mounted Near the 5-m Level on a Tower at the AFGL Weather Test Facility

3. DATA

During the 1980 data acquisition program, drop-size data were obtained in nine fogs over a total period of 70 h. Fog durations varied from 1 to 13 h. A list of the operating times and the durations are given for each fog in Table 2. In the 26-27 June fog, the two FSSPs were located at the 5-m level. In the other fogs the FSSPs were located at the 5-m and 30-m levels. The OAPs were also located at the 5-m and 30-m levels, but the 30-m OAP operated only during the fogs of 2-3 July and 3-4 July. The aspirator failed and could not be replaced by the end of the measurement program. The 5-m OAP operated in all fogs except the fog of 26-27 June. Occasionally, the OAP was not operated because of the paucity of large droplets. The objective was to collect drop-size data throughout the fog life cycle. The probes were turned on when the visibility began to decrease and were operated continuously until the fog dissipated. In most cases, the fog dissipated after sunrise.

Other data that were collected during fog occurrences included extinction coefficient, temperature, dew point, wind direction, and speed at the 5-, 15-, 30-, 45-, and 60-m levels. These data were collected continuously and recorded on magnetic tape.

Table 2. Operating Times for PMS Spectrometer System

Date	Start	Stop	Duration	
26-27 June	2149	0830	10 h	41 min
3 July	0300	0615	3	15
3-4 July	2105	0725	10	20
10-11 July	2029	0524	8	55
11-12 July	2024	0553	9	29
17-18 July	2039	0420	7	41
29 July	0420	0534	1	14
29-30 July	2205	0339	5	34
5-6 August	2023	0921	12	58

4. MICROPHYSICAL DATA ANALYSIS

4.1 Average Droplet Spectra

Describing a typical droplet spectrum for advection fogs is difficult since no two droplet spectra are alike. Drop-size spectra vary not only from one fog episode to another, but also during the life of a particular fog and with height above the ground. However, if we look at a variety of drop size distributions, such as those shown in the Appendix, we begin to see certain features that allow us to categorize the types of distributions. However, one has to be careful since the number of categories can get very large. Of all the droplet spectra observed, it would appear that most can be categorized as one of three types. An example of these three types is shown in Figure 6. The distributions shown represent 5-min averages. These three types are based on the shape of the spectra and not the number concentration. In other words, while these spectra, shown in Figure 6, are from relatively dense fogs (vis ~ 100 m), spectra from lighter fogs will also fall within these types. The common feature of these three samples, as well as all the other samples taken, is, without exception, the high concentration of particles below 2.5 μm; that is, apparently, the result of inactive or haze nuclei.

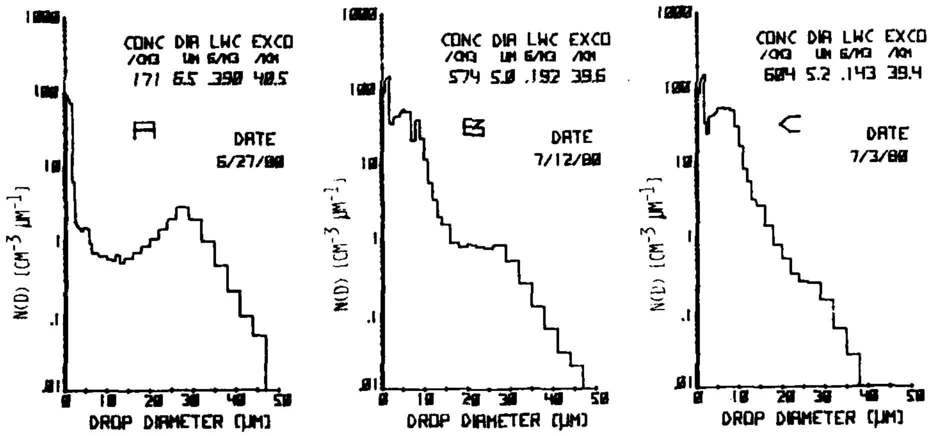


Figure 6. Three Types of Drop Size Spectra Observed in Advection Fogs at the WTF at Otis AFB

Before the advent of optical particle counters, the smaller particles went virtually undetected, since most impaction techniques do not detect droplets smaller than 5-μm diameter. However, using optical particle counters,

Hindman et al[3] reported the presence of haze particles in fogs at Trinidad, California, and Low et al,[4] observed submicron particles at Fort Ord, California, as did Pinnick et al,[5] in West Germany.

The middle spectrum (Type B) in Figure 6 might very well represent a typical or mean spectrum of the data collected. It is characterized by a primary mode between 0.5 and 2.0 μm, a secondary mode or plateau between 5 and 10 μm, and a plateau between 15 and 30 μm. The other two spectra represent the extremes of this "typical" spectrum. In Type A, a mode has developed in the 15 to 30 μm plateau. The high concentration in the 5- to 10-μm range is not present in this example, but quite often a trimodal distribution does exist. The distribution on the right (Type C) shows no plateau or peak in the 15- to 30-μm range, but shows a decrease in concentration that can be represented by a power law curve as described by Junge.[6] In this case, the number concentration per size interval, N(D), is proporational to $D^{-5.3}$ with a correlation of 0.95. Of all the samples taken in the nine fogs, approximately 60 percent of them were of Type B, that is a plateau in the 15- to 30-μm range. Approximately 30 percent of the distributions were of Type C, that is, a power law distribution, and only 10 percent of them showed the "classical" type of distribution with a mode existing in the larger droplet range (Type A).

The distribution of liquid water for the three types is shown in Figure 7. The most common distribution is bimodal with peaks at about 10 μm and 30 μm. The other two distributions show peaks at either 10 or 30 μm. The contribution of the different drop sizes to the extinction coefficient (EXCO)* for the three types is shown in Figure 8. In Type A, the small droplets contribute little to the EXCO, but do contribute significantly to the EXCO in the other two distributions.

---

*The extinction coefficient (EXCO) is related to visibility by Koschmieder's law.[7] Assuming a threshold contrast of 0.055, EXCO = 2.9/VIS where VIS is visibility.

3. Hindman, E.E. II, and Heimdahl, O.E.R. (1977) Sub-Micron Haze Droplets and Their Influence on Visibility in Fog, Preprint 6th Conf. On Inadvertent and Planned Weather Modification, pp 177-179.

4. Low, R.D.H., Duncan, L.D., and Hsiao, Y.Y.R.R. (1979) Microphysical and Optical Properties of California Coastal Fogs at Fort Ord, ASL-TR-0034.

5. Pinnick, R.G., Hoihjelle, D.L., Fernandez, G., Stenmark, E.B., Lindberg, J.D., Jennings, S.G., and Hoidale, G.B. (1978) Vertical Structure in Atmospheric Fog and Haze and Its Effect on IR Extinction, ASL-TR-0010.

6. Junge, C.E. (1963) Air Chemistry and Radioactivity, Academic Press, New York, 382 pp.

7. Koschmieder, H. (1924) Theorie der horizontalen sichtweite, Beitr. Phys. Atmos. 12:33-55.

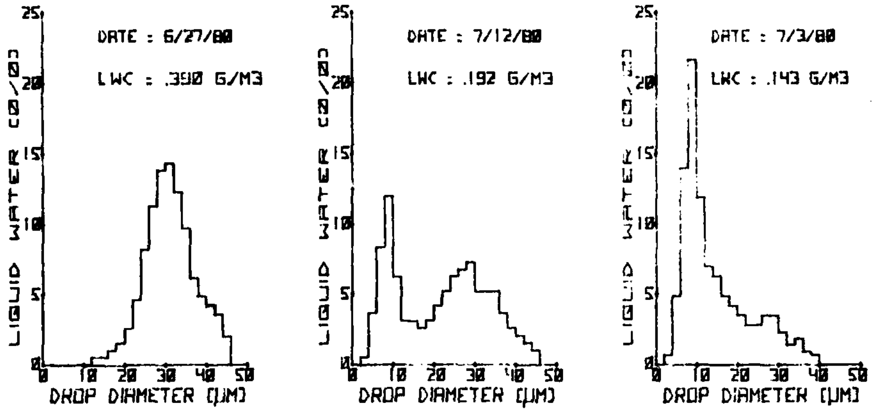


Figure 7. The Distribution of Liquid Water for the Three Spectra Shown in Figure 6

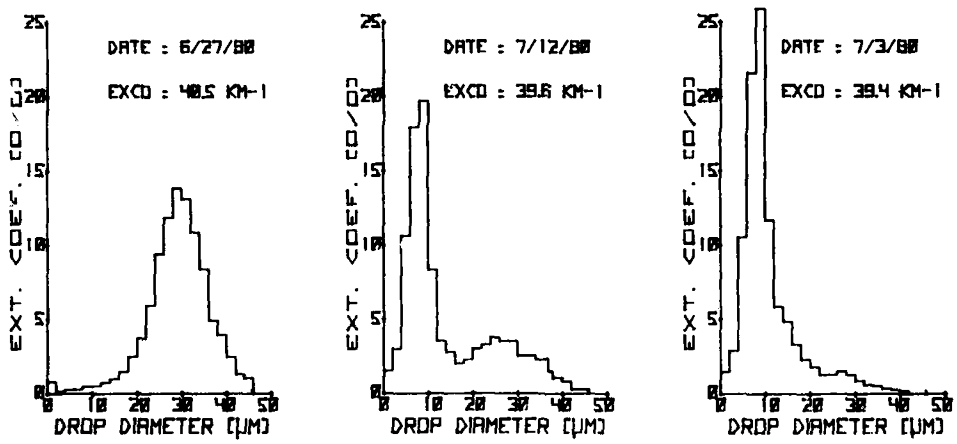


Figure 8. The Distribution of Extinction for the Three Spectra Shown in Figure 6

The cumulative frequency distributions for the three types are shown in Figure 9. Because of the lack of droplets in the 5- to 10-μm range, the Type A distribution shows a relatively high percentage of droplets above 10 μm. Types B and C show very similar distributions. The cumulative liquid water content varies considerably in the three distributions. The median volume diameter, which is defined as the diameter at which half the liquid water is contained in droplets

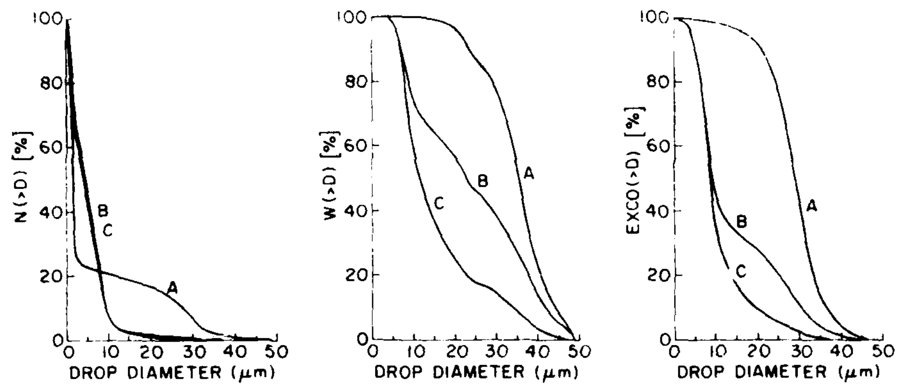


Figure 9. The Cumulative Frequency Distribution of Number Concentration, Liquid Water Content, and Extinction Coefficient for the Three Spectra Shown in Figure 6

larger than that diameter and half in droplets smaller than that diameter, varies from 12 μm for Type C to 36 μm for Type A. The contribution of the different drop sizes to the extinction coefficient also shows considerable variation. For instance, 50 percent of the extinction in Types B and C is due to droplets less than 10-μm diameter whereas only about 2 percent of the extinction in Type A is due to droplets less than 10 μm.

Most of the fog droplet spectra are confined to the range below 47 μm in diameter, the upper limit of the FSSP. However, the OAP shows that some fogs contain droplets ranging up to 200 μm. Figure 10 shows some examples of the simultaneous distributions obtained from the FSSP and the OAP, ranging from a sample with very few droplets >47 μm (3 July 0441 EDT) to one with a relatively large number of droplets >47 μm (5 August 2148 EDT). The number concentration of droplets >47 μm is usually less than 0.1 percent of the total, but as much as 30 percent of the liquid water and 10 percent of the extinction can be attributed to droplets >47 μm. The continuity between the two distributions is quite good, except in the 34-47 μm overlap region where the OAP is measuring lower concentrations than the FSSP.

An attempt was made to relate the droplet spectra to other measured parameters such as fog depth, extinction coefficient, wind direction and speed, and dew point. The only parameter that had an obvious influence on the droplet spectra was wind direction. The droplet concentration, especially below 10 μm, was affected by the trajectory of the air mass. When the air flow was from the southwest, large concentrations of droplets (500-700/cm^3 > 0.5 μm) were present.

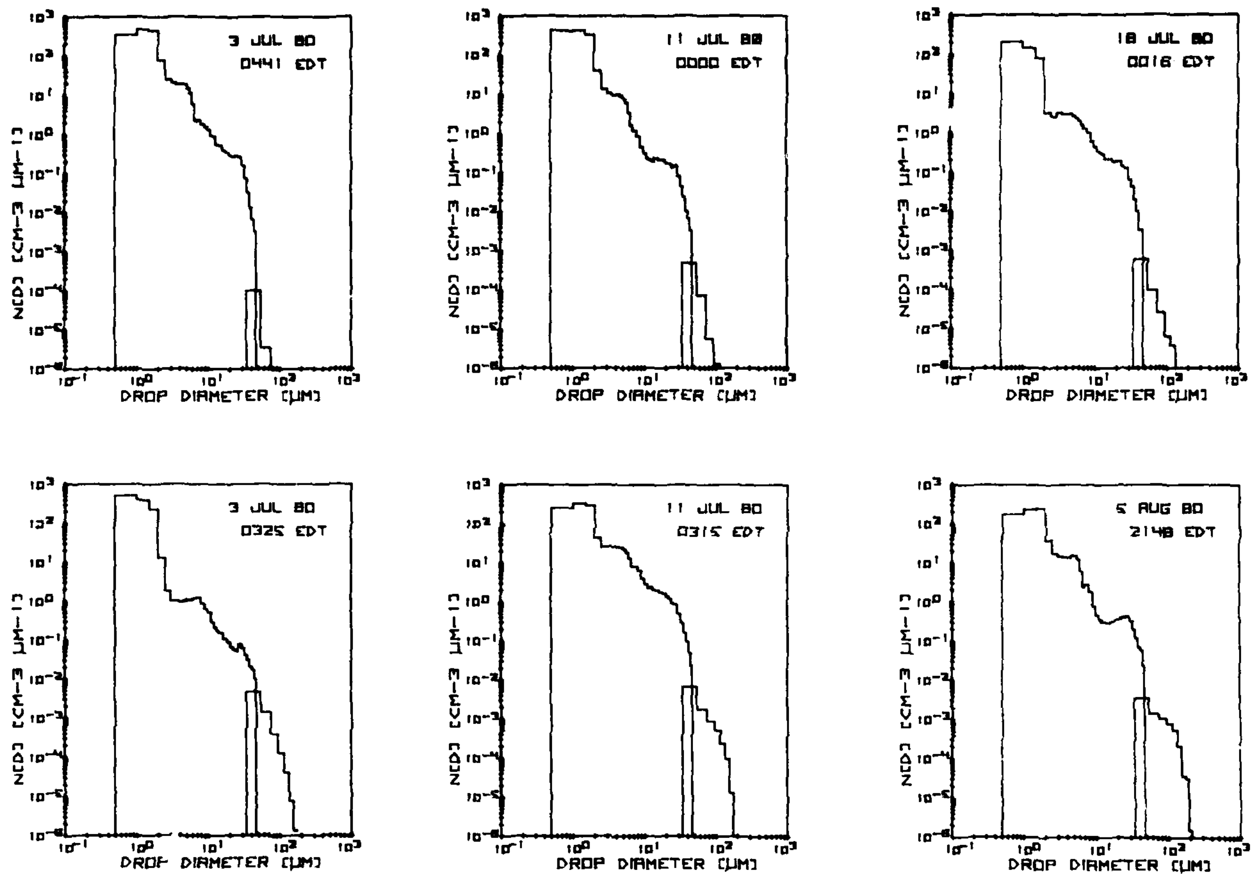


Figure 10. Examples of Simultaneous Drop Size Distributions Obtained With the FSSP (0.5-47 μm) and OAP (34-300 μm)

The air mass has a short overwater trajectory of 400-600 km and passes close to the industrial areas of New York and New Jersey. It is, therefore, influenced by the combustion products and photochemical processes from the land areas. Mack et al,[8] showed that during fogs with southwest wind at Otis AFB, only 9 percent of the droplets contained NaCl while 46 percent of them contained the element silicon (Si), which originates from continental sources. Fogs that occur when the air mass trajectory has a longer overwater fetch have a lower droplet count of 150-300/cm^3 for droplets >0.5 μm. This is evident in the fogs that occurred on the mornings of 29 and 30 July (see Table 3). During these two fogs the winds were from the east and south, respectively. The only obvious impact that the air mass trajectory has on the shape of the fog droplet spectra is at the small drop-size end of the spectra where the number of droplets <2 μm diameter is greatly reduced. Above 2 μm, the spectra can be similar to any one of the three spectra for a given wind direction. It is suspected that the shape of the droplet spectrum is affected primarily by the type of condensation nuclei present. A single source of nuclei will tend to produce a Type A distribution whereas a multiple source nuclei population will produce a Type B or C distribution.

4.2 Height Variation

In the eight fogs in which drop-size data were collected at both the 5-m and 30-m level, the extinction coefficients (EXCO) and liquid water contents (LWC) derived from the drop-size spectra increased with depth. Table 3 shows that at the 30-m level, the LWC and EXCO were generally three times as high as at the 5-m level. Since the 30-m OAP was not operating in most of the fogs, the 5-m OAP data were not included in the table. In this table, the concentrations have been divided into two groups, those particles between 0.5- and 2.5-μm diameter, which represent haze or inactive particles, and those droplets greater than 2.5-μm, which represent the fog droplets. The remaining parameters listed in Table 3 are based on the fog droplet data only. The exclusion of the haze particles has an insignificant effect on the LWC and EXCO but has a large effect on the mean diameters.

Figure 11 shows the percentage of time that the LWC is below a given amount at 5 m and 30 m above the ground. The data include 400 5-min samples with a LWC of at least 0.01 g/m^3 at the 5-m level.

---

8. Mack, E.J., Wattle, B.J., Rogers, C.W., and Pilie, R.J. (1980) Fog Characteristics at Otis AFB, MA, Calspan Corp. Final Report, AFGL-TR-80-0340, ADA 095358.

Table 3. The Mean Microphysical Parameters of the Fogs Observed at the WTF at Otis AFB, Mass.

Date	Height (m)	Total Haze Conc. <2.5 μm (cm^{-3})	Total Fog Conc. >2.5 μm (cm^{-3})	Mean Diam. (μm)	Mean Vol. Diam. (μm)	Median Vol. Diam. (μm)	LWC (g/m^3)	EXCO (km^{-1})
26-27 June	5	166	37	17.8	22.6	28.8	0.237	25.8
3 July	30	364	282	6.7	9.7	22.6	0.144	28.5
	5	609	106	6.1	10.6	26.5	0.058	9.6
3-4 July	30	241	336	7.9	10.7	18.8	0.214	43.9
	5	503	111	6.8	10.6	21.3	0.069	12.6
10-11 July	30	296	277	8.0	11.3	20.6	0.209	38.8
	5	499	65	8.1	13.1	24.4	0.076	11.2
11-12 July	30	254	325	7.5	10.8	22.7	0.214	40.2
	5	506	100	6.5	11.2	25.9	0.074	11.5
17-18 July	30	155	212	8.0	11.6	22.8	0.174	30.8
	5	333	64	8.1	13.4	25.3	0.081	11.6
29 July	30	82	208	8.7	11.0	20.4	0.157	29.1
	5	201	17	12.6	17.1	26.7	0.056	7.0
29-30 July	30	100	150	8.6	11.8	20.4	0.138	24.2
	5	135	27	11.0	16.1	26.3	0.053	7.0
5-6 August	30	271	300	6.9	10.1	22.1	0.158	31.4
	5	353	59	6.6	12.2	27.9	0.047	6.9

If it is assumed that the air between the two levels is well mixed and has a moist adiabatic temperature profile, the LWC lapse rate at 20°C is 0.063 g/m^3 per 25-m height interval (see Mack et al,[8]). The average lapse rate of the eight cases in which measurements were made at both levels is 0.110 $g/m^3/25$ m; much higher than the theoretical value. Possible reasons for this disparity are (1) a temperature lapse rate different than moist adiabatic, (2) slightly less than saturated conditions at the 5-m level, and (3) droplets near the ground being swept out by the vegetation. Another possibility is that the LWCs computed from the drop size data are larger than the actual LWCs as indicated in two independent studies by Kunkel[1] and Vali et al.[2] Kunkel found that the measured extinction coefficients ($EXCO_m$) were related to the computed extinction coefficients ($EXCO_c$) by the following expression,

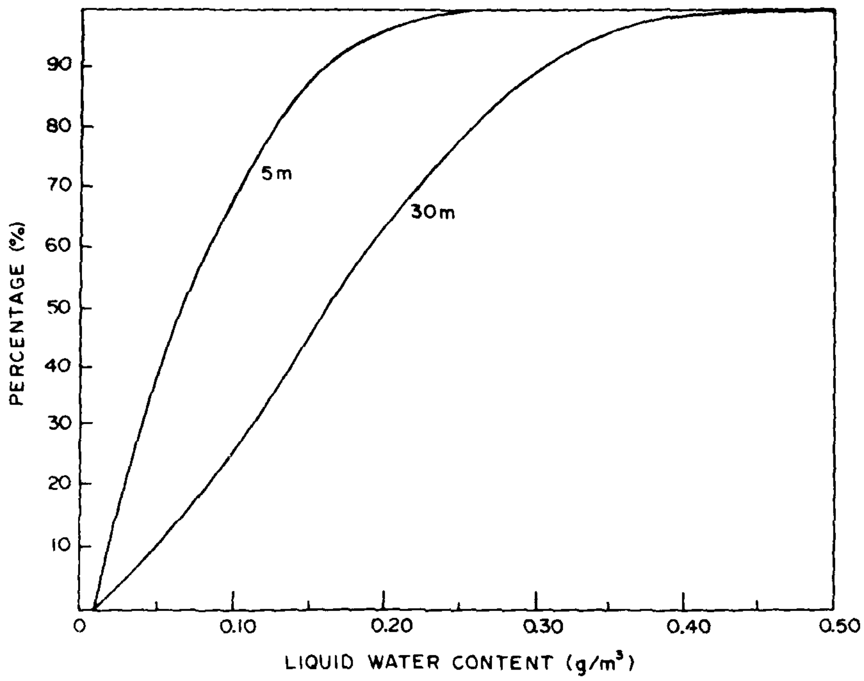


Figure 11. The Percentage of Time That the Liquid Water Content at 5 m and 30 m Above the Ground is Below a Given Value

$$(EXCO_m) = 2.156\ (EXCO_c)^{0.717} \quad . \tag{1}$$

Using Eq. (11), which relates the calculated LWC to the calculated extinction coefficient, we arrive at the following relationship between a modified liquid water content (W_m) and the calculated liquid water content (W_c),

$$W_m = 0.5\ W_c^{0.717} \tag{2}$$

Using this expression, the liquid water content lapse rate reduces to 0.073 g/m^3/ 25 m for the eight cases, a value reasonably close to the theoretical value of 0.063.

There are differences in the drop-size spectra at the two levels that are common to most fogs. These differences can be seen in the drop-size spectra shown in Figure 12. They include:

a. higher concentrations of droplets <2-μm diameter at the 5-m level,

10-11 JUL 80

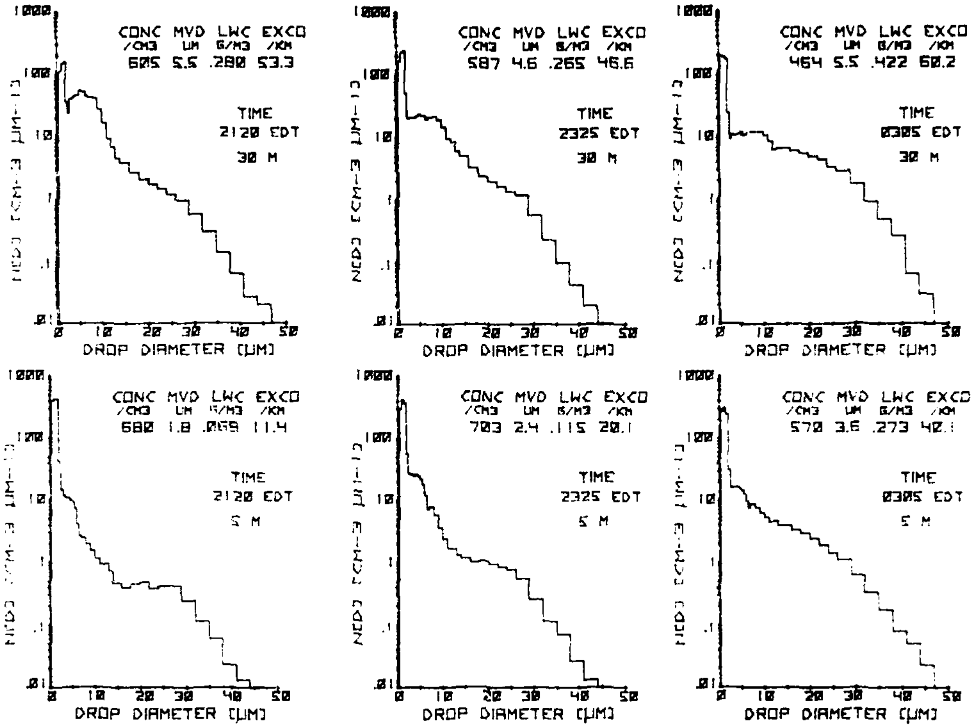


Figure 12. A Time Sequence of Droplet Spectra at the 5-m and 30-m Levels During an Advection Fog on the Night of 10-11 July 1980

b. lower concentrations and less pronounced peak in the droplet spectra between 5 and 10 μm at the 5-m level, and

c. Lower concentrations and often flatter distributions between 15 and 30 μm at the 5-m level.

In the first five fogs in Table 3 in which measurements were taken at both levels, the total concentration (0.5 to 47 μm) of droplets is, approximately, the same at both levels. In the latter three fogs, the total droplet count at 30 m is considerably higher. In the first five fogs, the peak concentration at the 5-m level is in the 1.0- to 2.0-μm range whereas in the latter three fogs the peak concentration at 5-m occurs in the 0.5- to 1.0-μm range. This would indicate that, in the latter three fogs a considerable number of particles existed below 0.5 μm at the 5-m level. As the air rises to the 30-m level, condensation occurs, resulting in an increase in the number of droplets >0.5 μm at the 30-m level.

Looking at an individual case, there is a surprisingly good correlation of 93 percent between the slope of the distribution between 0.5- to 1.0-μm and 1.0- to 1.5-μm size ranges at 5 m and the total concentration of particles at 30 m relative to the total concentration at 5 m (Figure 13). Correlating the slope of the distribution at 5 m with the extinction coefficient at 30 m produces a correlation of only 63 percent. This is not surprising since the extinction is also dependent on the drop-size distribution. Perhaps with a more detailed description of the size distribution of smaller droplets at ground level and the use of a droplet growth model, it may be possible to calculate visibilities at higher levels or the slant visual range over a finite depth.

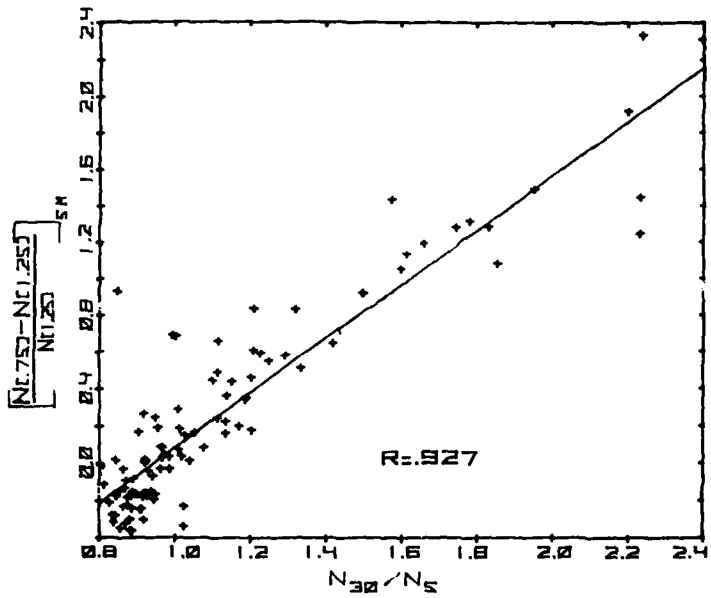


Figure 13. A Linear Regression Line Between the Slope of the Distribution Between 0.5-1.0 μm and 1.0-1.5 μm Size Ranges at 5 m and the Total Concentration of Particles at 30 m Relative to the Total Concentration at 5 m

4.3 Temporal Variation

The evolution of a fog episode may be divided into three stages: the formative, mature, and dissipative stages. Figure 14 shows an example of the variation in the mean diameter, mean volume diameter, concentration, liquid water content, and extinction coefficient during the three stages of a fog episode that occurred on

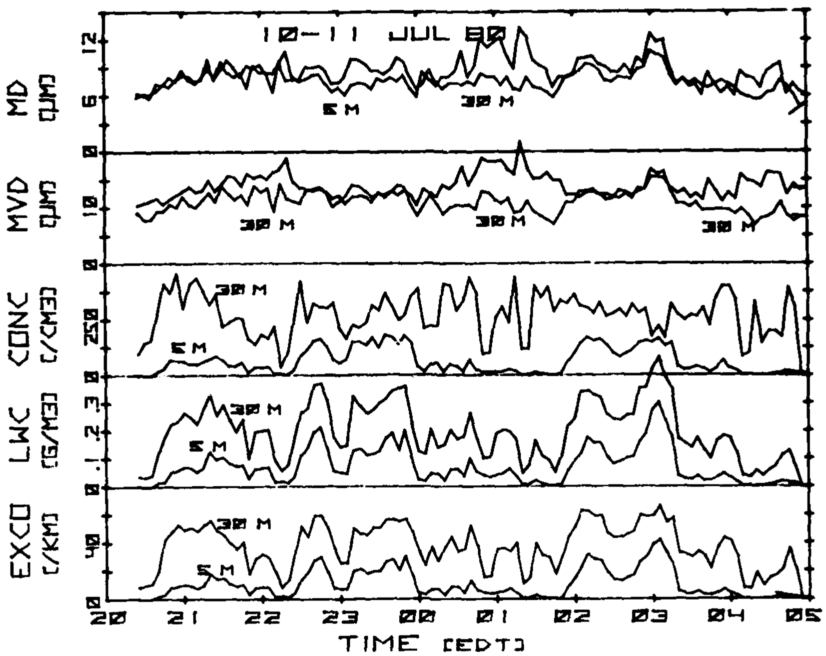


Figure 14. The Temporal Variation of the Microphysical Parameters During a Fog on the Night of 10-11 July 1980. Data apply to fog droplets between 2.5 and 47-μm diameter

the night of 10-11 July 1980. In this figure, the parameters apply only to the fog droplet data (that is, droplets >2.5-μm diameter).

In the formative stage, the droplet concentrations increase, resulting in increasing LWCs and EXCOs. The mean size of the fog droplets does not necessarily increase during this stage. Generally, in the fogs observed, this formative stage lasts for approximately one hour at which time the EXCO and LWC reach a maximum. During the mature stage, which may last as long as 7 or 8 h, the droplet concentration and sizes may vary considerably. Changes are random and the resulting visibilities may frequently rise above airfield minimums, which for a Category II landing system is 1/2 mile or an EXCO of 3.7/km. This variability makes it difficult to predict above minimum conditions during a fog episode. The dissipative stage is a period of decreasing concentration and usually decreasing drop size. This stage may last up to two hours. Fluctuations in droplet concentration and size during this period are common, which make it difficult to define the beginning of this stage. Temporal variations of microphysical parameters of other fog episodes are presented in the Appendix.

The variation in the slope of the droplet spectra can b · be observed in a three-dimensional (3D) plot that shows the variation in the droplet spectra with time. Figure 15 shows the variation in the droplet spe^tra at the two levels during the fog of 10-11 July 1980. Droplet counts below $0.1/cm^3/\mu m$ were rounded off to 0.1 for illustrative purposes. The size bins vary from 0.5 μm at the small end to 3 μm at the large end.

The time and height variability is typical of most of the observed coastal fogs. Some of the characteristics of the spectra worth noting and common in many of the fogs are:

a. the relatively high counts in the size range below 2.5-μm diameter,

b. droplet concentrations increase (decrease) simultaneously in all size bins >1 μm when fog occurs (dissipates),

c. Droplet concentrations in the 0.5- to 1.0-μm size bin decrease (increase) when fog occurs (dissipates), and

d. the existence of more than one type of spectrum during the life cycle of a fog episode.

Time plots of the droplet spectra for the other fogs are presented in the Appendix.

5. MODEL APPLICATIONS

In order to predict visibilities with a fog prediction model, a knowledge of the drop-size distribution is desirable. However, introducing the type and concentration of condensation nuclei into a model and calculating the resulting droplet spectrum greatly increases its complexity. Using empirically derived formulas can greatly simplify a model. An attempt is made here to use the drop-size data to develop two such empirical formulas. One formula relates the mean droplet terminal velocity, used in computing the gravitational flux of liquid water, to the LWC and droplet concentration. The other formula relates the EXCO, or visibility, to the LWC.

5.1 Mean Terminal Velocity

The weighted mean velocity of the falling drops can be determined from

$$\overline{V}_T = \frac{4/3\pi \sum_{i=1}^{N} (n_i\, r_i^3\, v_i)}{W} , \qquad (3)$$

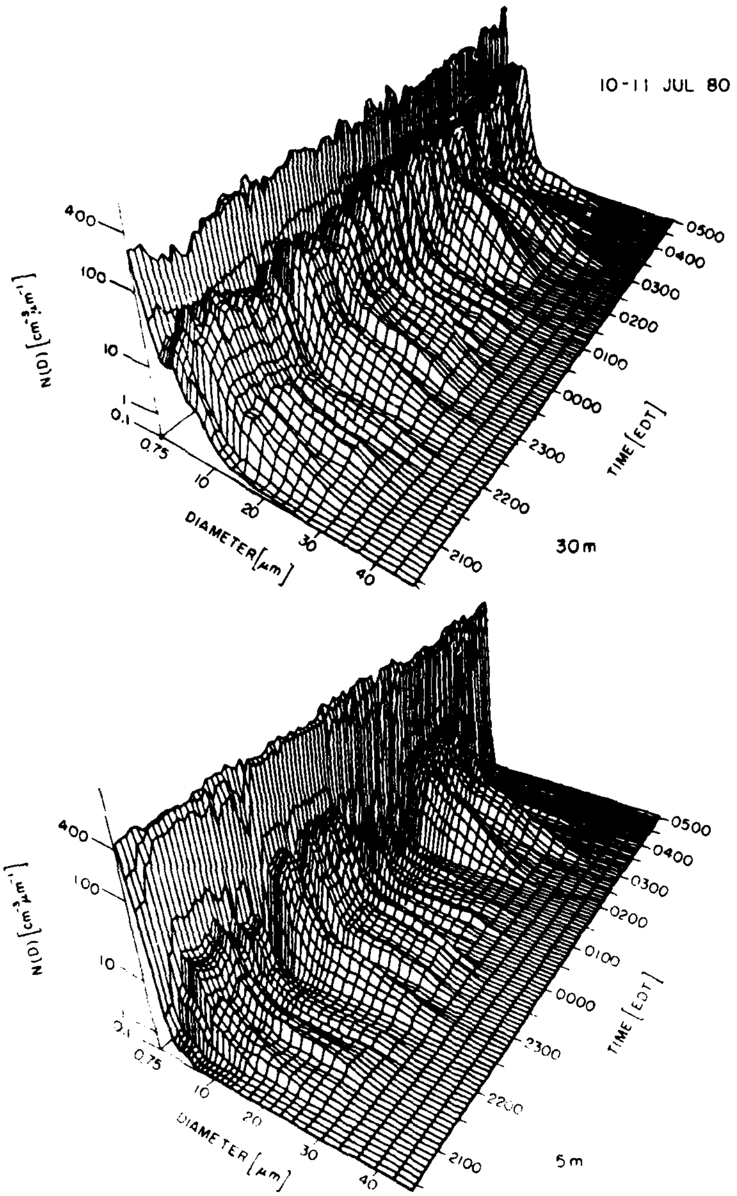


Figure 15. A Three-Dimensional Time Plot of the Droplet Spectra at the 5-m and 30-m Levels for a Fog on the Night of 10-11 July 1980

where n, r, and v, are the number concentration, radius, and terminal velocity of droplets in a given size range i. W is the total liquid water content. The terminal velocity of droplets is given by Stoke's law,

$$v_i = 1.202 \times 10^{-2} r_i^2 \quad , \tag{4}$$

where r_i is in microns and v_i in cm/sec. The $\overline{V}_T$, computed for each droplet sample, was then correlated with the number concentration of droplets greater than 0.5-μm diameter, the concentration of droplets greater than 2.5μm, the LWC, and $(W/N)^{2/3}$ where N is the concentration of droplets greater than 2.5μm. The latter parameter was used in the Calspan fog prediction model (Rogers et al[9]). Over 800 5-min samples were taken at the 30-m level during eleven fogs, three of which occurred in 1981. The correlations and linear regression lines between V_T and the other parameters are shown in Figure 16. Although none of the correlations are particularly high, the mean terminal velocity correlates best with $(W/N)^{2/3}$. In general, $\overline{V}_T$ ranges from 1.0 to 2.5 cm/sec. Since correlations are not very good, using an average $\overline{V}_T$ of 1.8 cm/sec in fog prediction models may be sufficient. An independent check of the four relationships in Figure 16 was made using data from four urban type radiation fogs that occurred at Hanscom AFB, Mass. during the fall of 1980. The mean terminal velocities agreed quite well with those derived from the Otis advection fogs.

In the fog model described by Rogers et al,[9] $\overline{V}_T$ is equal to $3.5\ W^{2/3}$, assuming a droplet count of 50 cm^{-3}. Brown[10] in a radiative fog model uses the relationship $\overline{V}_T = 2.1$ W in urban fogs (that is, fogs of high condensation nuclei concentration) and $\overline{V}_T = 5.2$ W in rural fogs (low nuclei concentration). A comparison of the Brown and Rogers et al V_T vs W relationships with the Otis data is shown in Figure 17. The Otis data reveals that in light to moderate fogs, V_T is consistently higher than those derived from either the Brown or Rogers et al relationships. The higher mean terminal velocities in the light to moderate fogs may be a result of the large sample volume, which allows detection of the few large droplets that might be present and contribute significantly to the LWC. For each measurement, the droplet counts were accumulated over a 5-min period resulting in a sample volume of 500 cm^3 for droplets up to 26 μm and 1000 cm^3 for droplets greater than 26 μm. Even in the very light fogs (that is, with $W \sim 0.1\ g/m^3$) droplets up to 30-μm diameter were detected.

---

9. Rogers, C.W., Eadie, W.J., Katz, U., and Kocmond, W.C. (1975) Project Fog Drops V, NASA CR-2633, 55 pp.

10. Brown, R. (1980) A numerical study of radiation fog with an explicit formulation of microphysics, Quat. J.R. Met. Soc. 106:781-802.

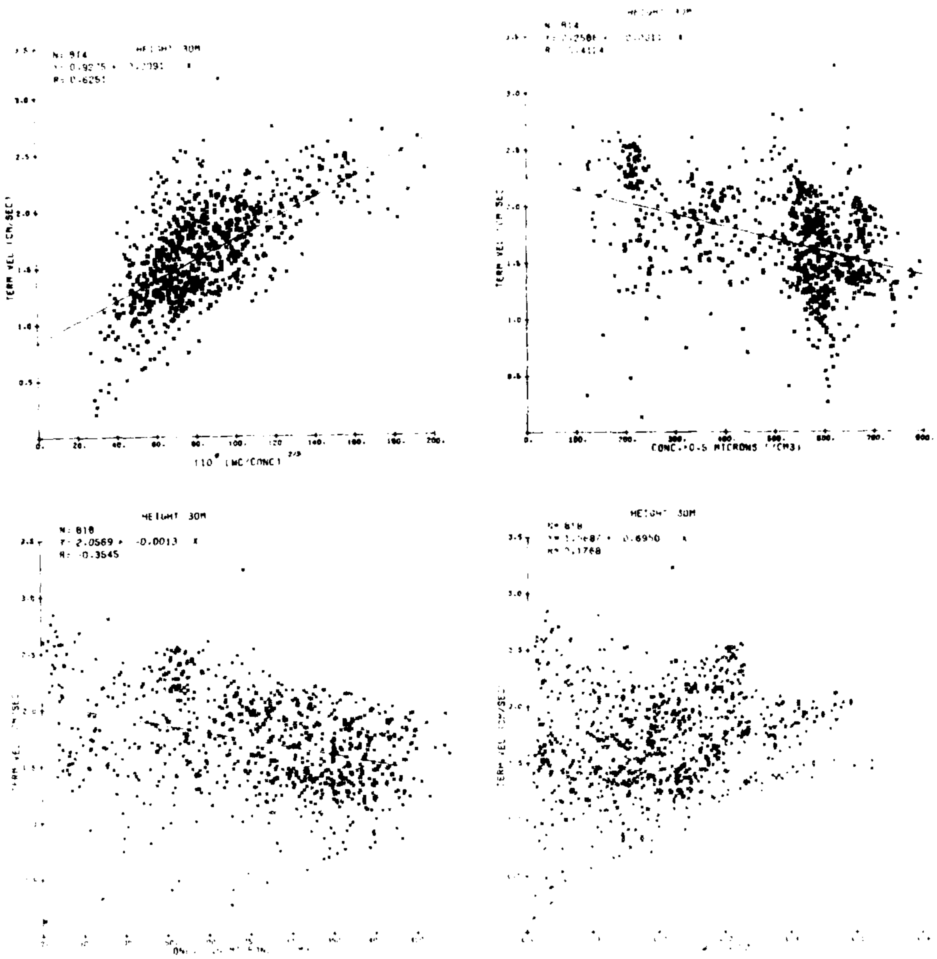


Figure 16. Linear Regression Lines Relating the Mean Droplet Terminal Velocity With Various Microphysical Parameters

5.2 Extinction Coefficient/Liquid Water Content Relationship

Fog prediction models predict the liquid water content. To be of practical use, this liquid water content (W) must be converted to an EXCO, or visibility. If the drop-size distribution is known, then the EXCO can be readily determined. Otherwise, an empirical formula must be used to relate the liquid water content to the extinction coefficient.

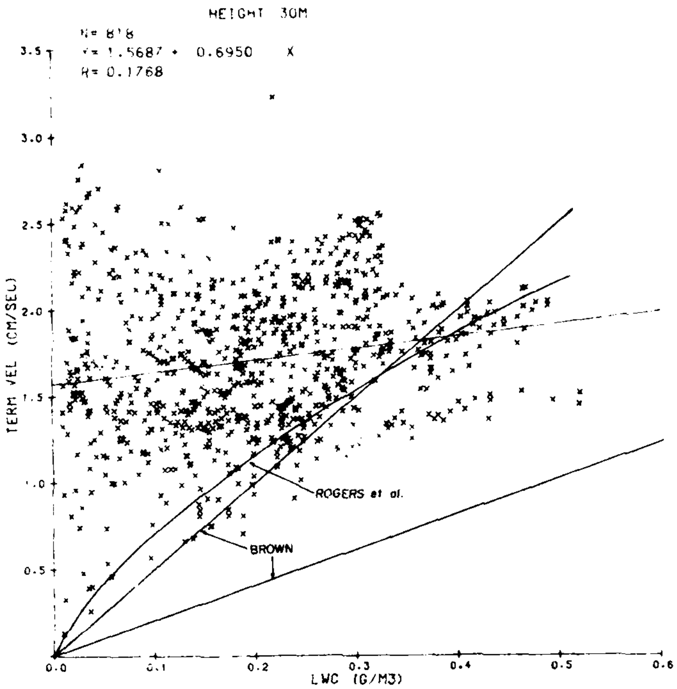


Figure 17. A Comparison of the Mean Terminal Velocity/Liquid Water Content Relationship Derived from the Otis Data With Those Derived by Brown[10] and Rogers[9]

Eldridge[11] derived the following empirical relation for "stable and evolving" fogs based on fog drop-size distributions inferred from measured spectral transmission through fog with the aid of Mie scattering theory. The droplet range measured was from 0.6- to 16-μm diameter,

$$\mathrm{EXCO} = 163\ (W)^{0.65} \tag{5}$$

Eldridge[12] later modified the relationship by extending the upper limit of his drop-size spectra by using data collected by Houghton and Radford.[13] With his new distributions, he arrived at the following relationship,

11. Eldridge, R.G. (1966) Haze and fog aerosol distributions, J. Atm. Sci. 23:605-613.
12. Eldridge, R.F. (1971) The relationship between visibility and liquid water content in fog, J. Atm. Sci. 28:1183-1186.
13. Houghton, H.G., and Radford, W.H. (1938) On the measurement of drop size and liquid water content in fogs and clouds, Papers Phys. Oceanogr. Meteor. 6(No. 4):31 pp.

$$EXCO = 91 (W)^{0.65} \quad . \tag{6}$$

Pinnick,[5] collecting drop-size data at different heights in German fogs using a PMS Classical Scattering Aerosol Spectrometer mounted on a tethered balloon, arrived at the relationship,

$$EXCO = 145 (W)^{0.63} \quad . \tag{7}$$

The size range of the instrument was limited and, depending on conditions, was set at either 1- to 32-, 0.75- to 16-, or 0.6- to 8-μm diameter. Once the instrument and balloon were raised, the range setting could not be changed, thus resulting in many distributions being severely truncated at the upper end of the spectra.

Tomasi et al,[14] using modified gamma size distribution models derived from empirical size spectra of fog droplets, arrived at the following relationship for "wet and warm" fogs,

$$EXCO = 65 (W)^{2/3} \tag{8}$$

and for "dry and cold" fogs,

$$EXCO = 115 (W)^{2/3} \quad . \tag{9}$$

Since the Otis droplet spectra data represent the first set of known data that cover the complete fog droplet spectra range above 0.5-μm diameter, the EXCO/W relationship was re-examined. A power law curve was fitted to the data for each fog case. The exponent ranged from 0.96 to 1.14 and the constant ranged from 110 to 253. The relationship for each case is illustrated in Figure 18 where the calculated extinction coefficients are plotted against the calculated liquid water content and a least square power law curve is drawn. Taking all the data from both the 5- and 30-m levels from each case and correlating, a mean relationship was derived (Figure 19)

$$EXCO = 154.9 (W)^{0.94} \quad , \tag{10}$$

which can be approximated by the linear relationship

$$EXCO \sim 164 W \quad . \tag{11}$$

---

14. Tomasi, C., and Tampieri, F. (1976) Features of the proportionality coefficient in the relationship between visibility and liquid water content in haze and fog, Atmosphere 14(No. 2):61-76.

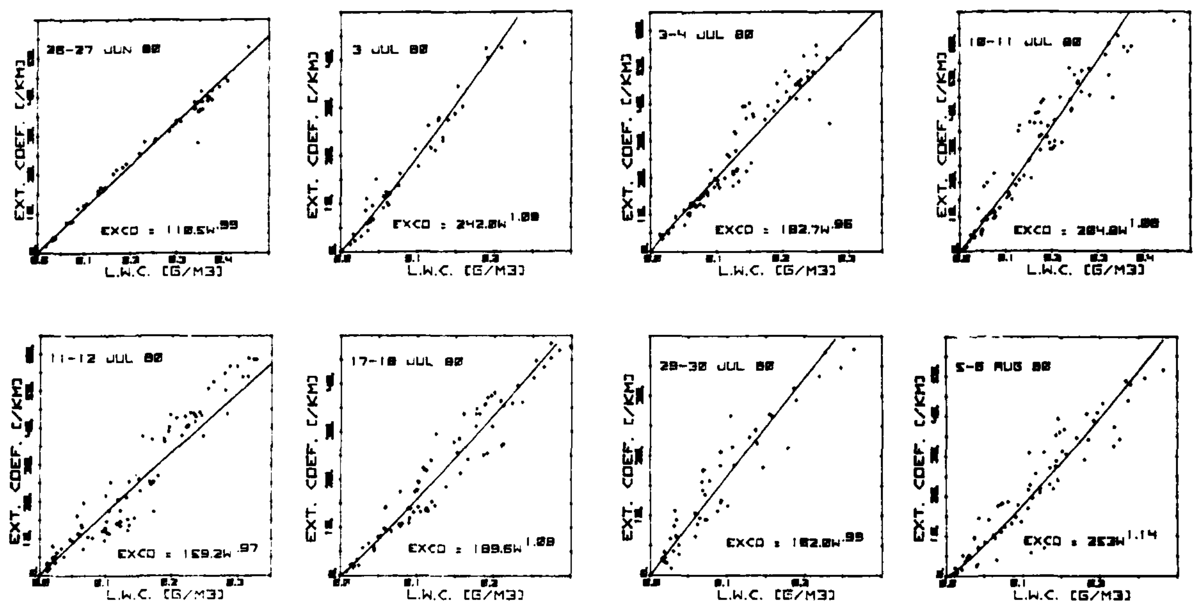


Figure 18. The Relationships Between Extinction Coefficient and Liquid Water Content for Eight Advection Fog Cases

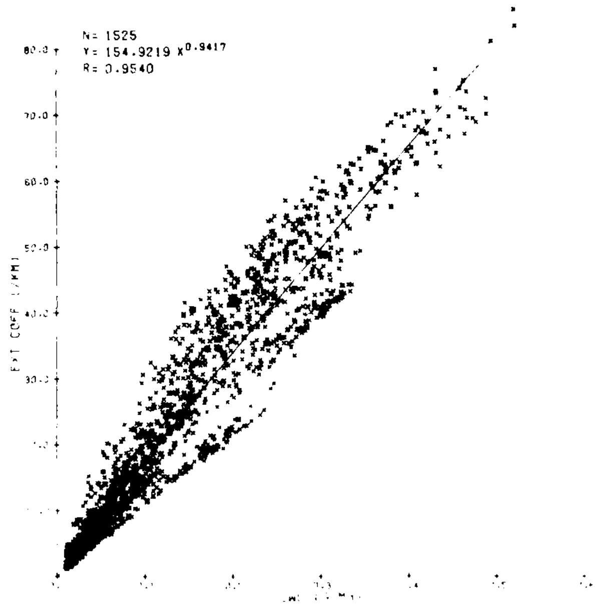


Figure 19. The Mean Relationship Between Extinction Coefficient and Liquid Water Content Derived From Data Taken at the 5- and 30-m Levels

The near linear relationship is due to the fact that the observed droplet spectra does not change significantly with the liquid water content. The two-thirds relationship found by the other investigators results from their observations of *smaller droplets in the lighter fogs than in the denser fogs.*

Figure 20 shows a comparison of the various relationships. It is interesting to note that both Eldridge (Curve A) and Pinnick (Curve C) curves, which are based on data truncated at the upper end of the spectra, give high extinction coefficients for a given liquid water content. The revised Eldridge curve (B) for the most part falls within the two extremes (dashed lines, F&G) of the Otis data. Curve F is representative of a fog with small droplets but high concentration and Curve G is representative of a fog with large droplets but low concentration. Curve E is the average relationship for the Otis fogs. Tomasi's curves for wet and warm fogs (D1) and dry and cold fogs (D2) agree quite well with the extremes for the Otis data.

In summary, the new parameterizations of terminal velocity and EXCO mean that, when included in the parameterized advection fog models, the LWCs will be lower and visibilities higher than with most other parameterizations, especially in light fogs. The reason is that the observed large droplets in the light fogs

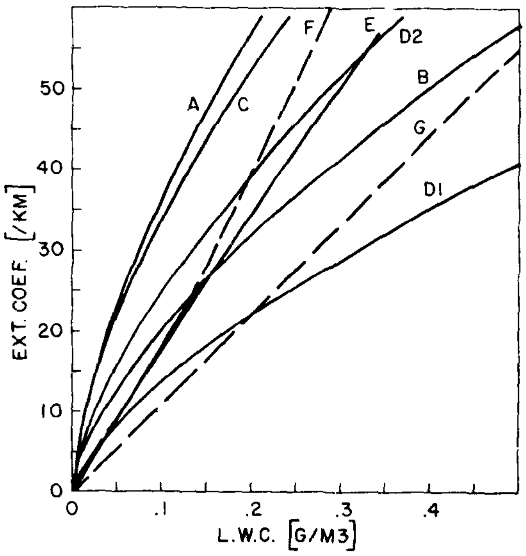


Figure 20. A Comparison of Various Relationships Between Extinction Coefficient and Liquid Water Content. Curve A&B – Eldridge,[11,12] Curve C – Pinnick et al,[5] Curve D1 & D2 – Tomasi *et al*,[14] Curve E, F&G – Extremes and Average of Otis Data

result in relatively high visibilities for a given liquid water content and in more rapid fallout of the droplets, which reduces the LWC and increases the visibility.

References

1. Kunkel, B.A. (1981) Comparison of Fog Drop Size Spectra Measured by Light Scattering and Impaction Techniques, AFGL-TR-81-0049, ADA 100252.
2. Vali, G., Politovich, M.K., and Baumgardner, D.G. (1981) Conduct of Cloud Spectra Measurements, AFGL-TR-81-0122, ADA 102944.
3. Hindman, E.E. II, and Heimdahl, O.E.R. (1977) Sub-Micron Haze Droplets and Their Influence on Visibility in Fog, Preprint 6th Conf. on Inadvertent and Planned Weather Modification, pp 177-179.
4. Low, R.D.H., Duncan, L.D., and Hsiao, Y.Y.R.R. (1979) Microphysical and Optical Properties of California Coastal Fogs at Fort Ord, ASL-TR-0034.
5. Pinnick, R.G., Hoihjelle, D.L., Fernandez, G., Stenmark, E.B., Lindberg, J.D., Jennings, S.G., and Hoidale, G.B. (1978) Vertical Structure in Atmospheric Fog and Haze and Its Effect on IR Extinction, ASL-TR-0010.
6. Junge, C.E. (1963) Air Chemistry and Radioactivity, Academic Press, New York, 382 pp.
7. Koschmieder, H. (1924) Theorie der horizontalen sichtweite, Beitr. Phys. Atmos. 12:33-55.
8. Mack, E.J., Wattle, B.J., Rogers, C.W., and Pilie, R.J. (1980) Fog Characteristics at Otis AFB, MA, Calspan Corp. Final Report, AFGL-TR-80-0340, ADA 095358.
9. Rogers, C.W., Eadie, W.J., Katz, U., and Kocmond, W. C. (1975) Project Fog Drops V, NASA CR-2633, 54 pp.
10. Brown, R. (1980) A numerical study of radiation fog with an explicit formulation of the microphysics, Quat. J.R. Met Soc. 106:781-802.
11. Eldridge, R.G. (1966) Haze and fog aerosol distributions, J. Atm. Sci. 23:605-613.
12. Eldridge, R.G. (1971) The relationship between visibility and liquid water content in fog, J. Atm. Sci. 28:1183-1186.

13. Houghton, H.G., and Radford, W.H. (1938) On the measurement of drop size and liquid water content in fogs and clouds, Papers Phys. Oceanogr. Meteor. **6**(No. 4):31 pp.

14. Tomasi, C., and Tampieri, F. (1976) Reatures of the proportionality coefficient in the relationship between visibility and liquid water content in haze and fog, Atmosphere **14**(No. 2):61-76.

Appendix A

Meteorological Data

Case 1: 26-27 June 1980
(see Figures A1 through A7)

Time Period (vis < 1 mi)	2310-0710 EDT
Duration	8 h
Wind Direction	240^{o}
Wind Speed	8-10 knots
Temperature	$67^{o}F$
Estimated Depth	100 m
Comments	Shallow fog, large drops, drizzle reported. Fog preceded for several hours by low stratus. Stratus broke up about 0800.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SURFACE WEATHER OBSERVATIONS
(Abridged for use at designated Civil Stations)

OTIS TOWER
6/26–27/80

To convert LST to GMT ADD ____ hrs | Time in Column 2 is GMT ____ LDT X

Type (1)	Time (2)	Sky and Ceiling (Hundreds of feet) (3)	Visibility (miles) Surface (4)	Visibility Tower (4a)	Weather and Obstructions to Vision (5)	Sea Level Press. (6)	Temp (°F) (7)	Dew Pt (°F) (8)	Wind Direction (9)	Wind Speed (kts) (10)	Wind Character (11)	Altim. Setting (12)	Remarks and Supplemental (13)
SA	1856	M10 OVC	10				75	71	20	10			
SA	1955	M8 OVC	7				71	70	20	10			
SA	2055	M4 BKN 6 OVC	5		F		71	70	21	06			
SP	2133	M3 OVC	3		F				21	06			
SA	2155	W2X	2		F		70	70	21	08			
SA	2255	W1X	1		F		70	70	21	10			
SP	2320	W1X	1/2		L-F				21	10			
SA	2355	W1X	1/2		L-F		69	69	21	10			
SA	0055	W1X	1/2		L-F		69	69	21	10			
SA	0155	W1X	1/2		L-F		68	68	20	10			
SA	0255	W1X	1/2		L-F		68	68	20	10			
SA	0355	W1X	1/2		L-F		67	67	20	10			
SA	0455	W1X	1/2		F		67	67	20	10			
SP	0535	W1X	1/4		F				20	10			
SA	0555	W1X	1/4		F		66	66	22	10			
SA	0655	W1X	1/4		F		67	66	26	07			R23VR 10-
SP	0740	-X	1		F				26	05			
SP	0755	-X E5 BKN	2		F		68	66	26	08			
SP	0815	-X 5 SCT 100 SCT	7						27	10			

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY (Midnight to Midnight)

Figure A1. Surface Weather Observations Taken at the FAA Tower .)tis AFB

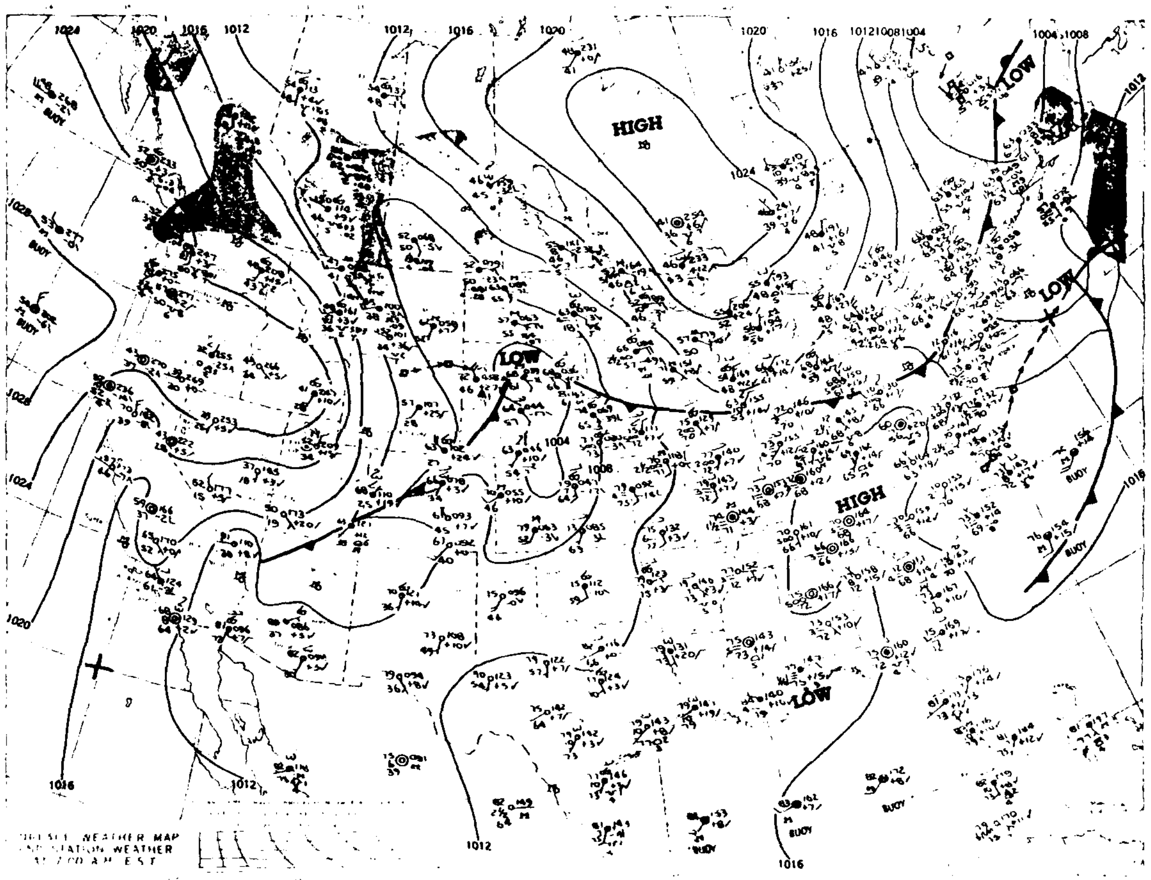


Figure A2. Surface Weather Map for 0800 EDT on 27 June 1980

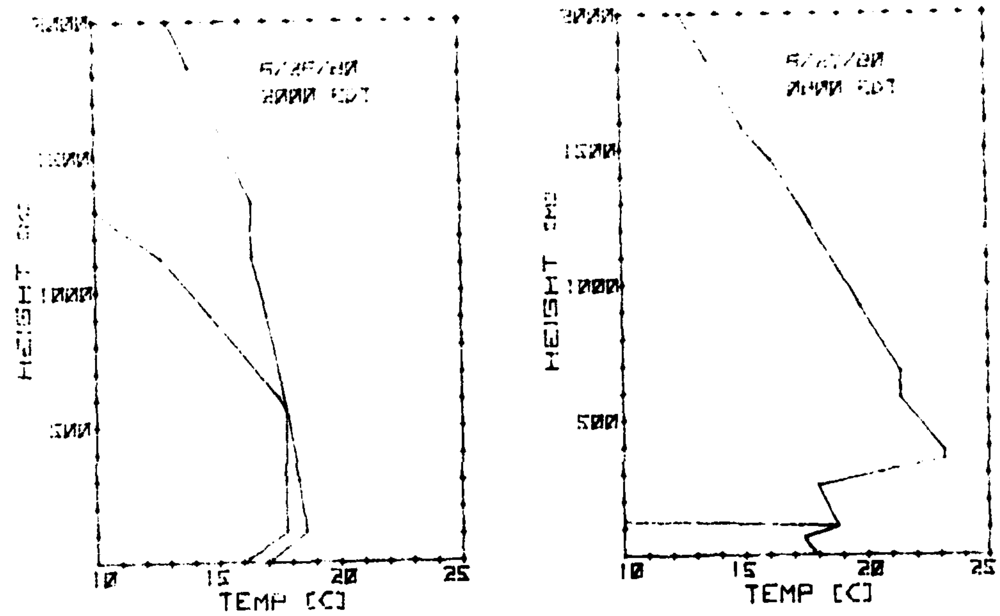


Figure A3. Chatham Radiosonde Soundings Before and After the Fog Episode

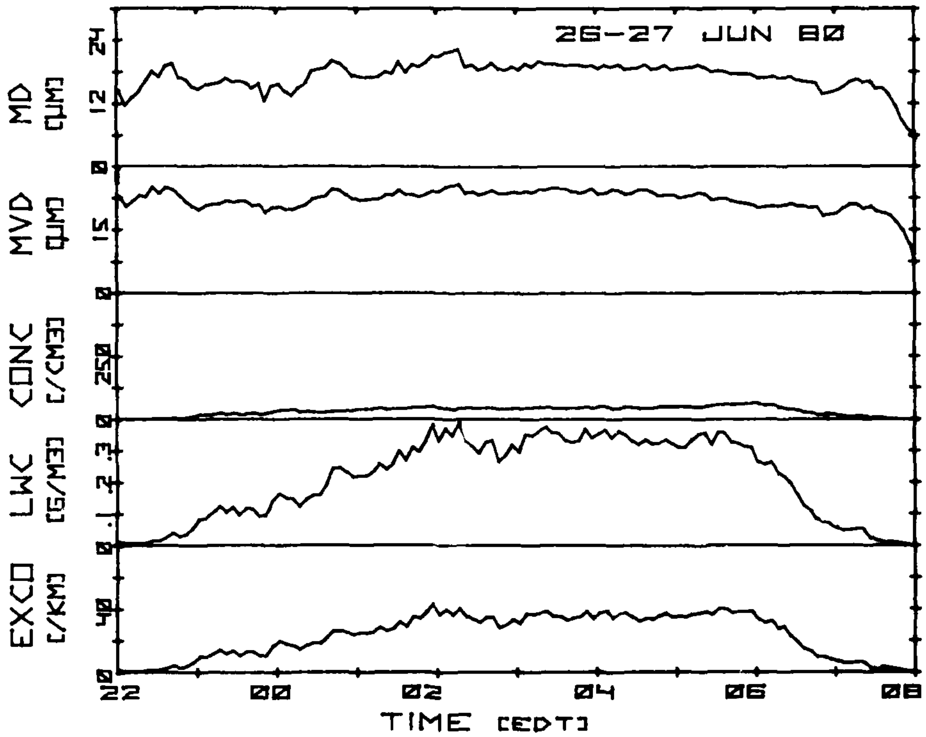


Figure A4. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

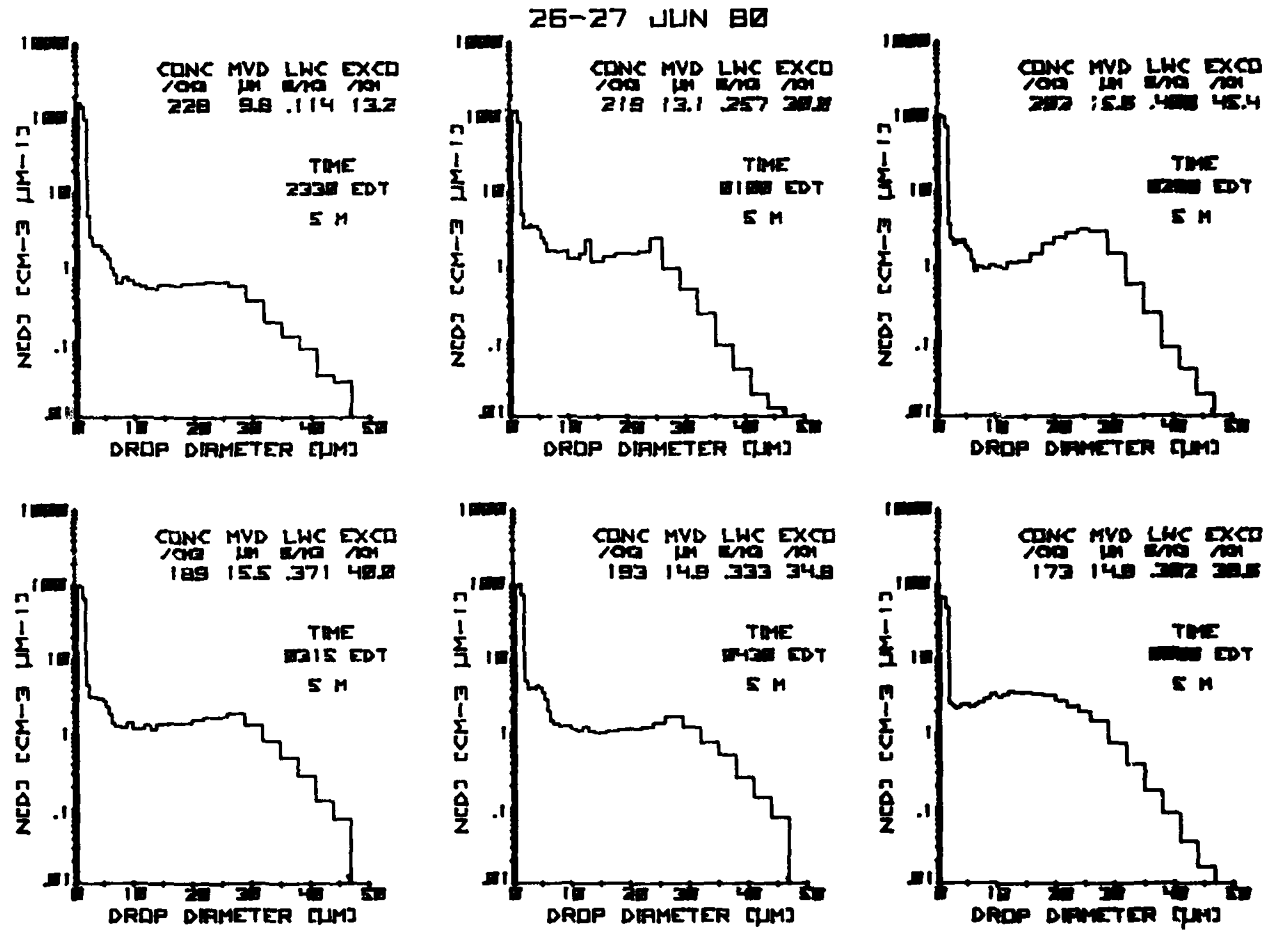


Figure A5. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level

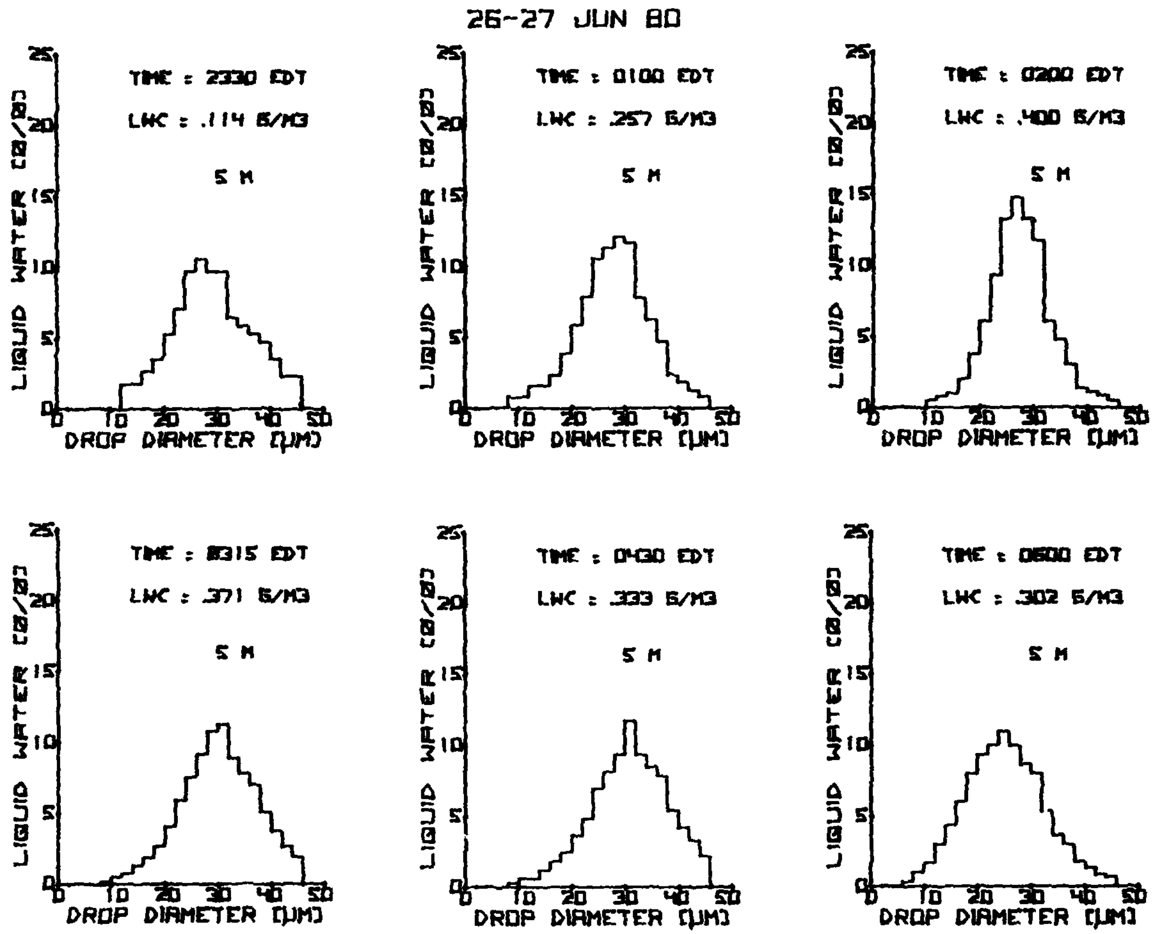


Figure A6. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m Level

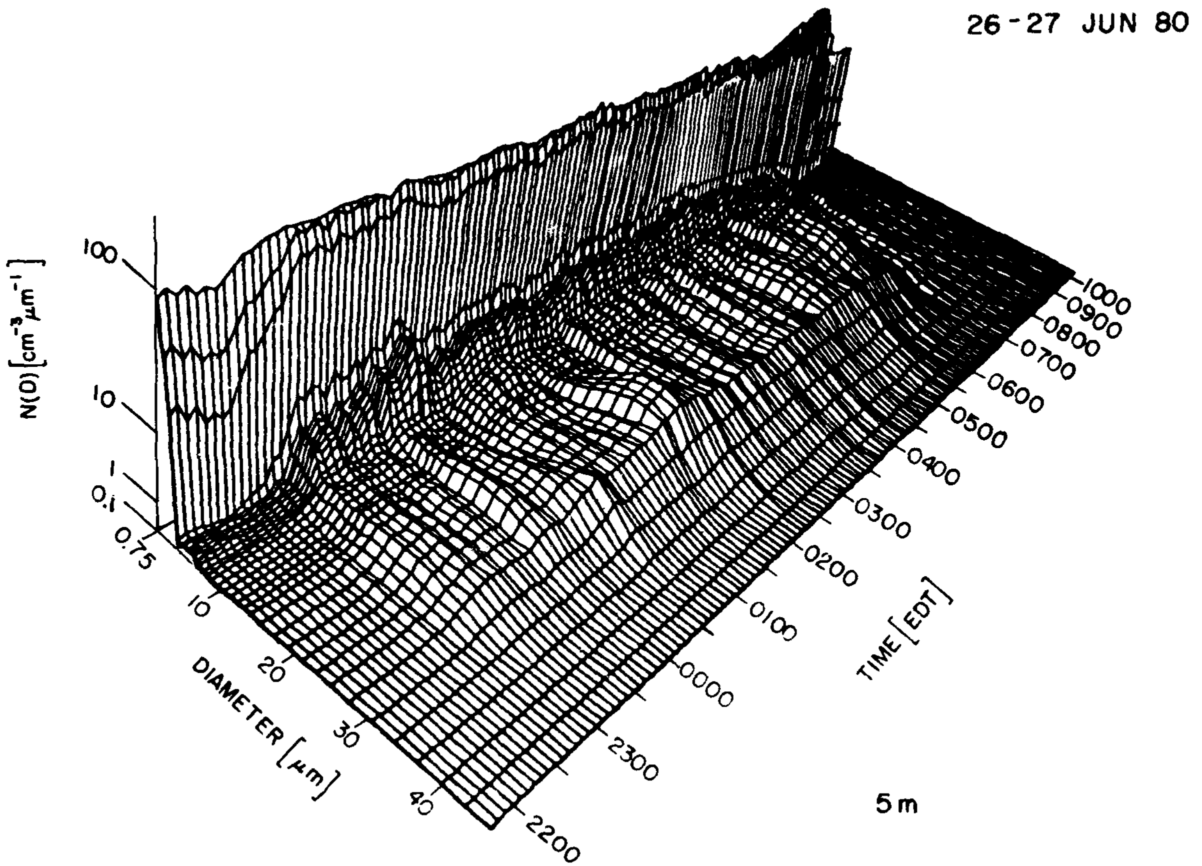


Figure A7. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level

Case 2: 2-3 July 1980
(see Figures A8 through A14)

Time Period (vis < 1 mi)	0340-0615 EDT
Duration	2 h 35 min
Wind Direction	Calm
Wind Speed	Calm
Temperature	69°F
Estimated Depth	200 m
Comments	Fog preceded by low stratus, showers and thundershowers. Fog lifted after sunrise and low stratus broke up about 0800.

SURFACE WEATHER OBSERVATIONS

OTIS TOWER
7 2- 3 80

Time in column 2 is: LST X

Type	Time	Sky and ceiling	Visibility: Surface	Visibility: Tower	Weather and obstructions to vision	Sea level press.	Temp	Dew pt	Wind direction	Wind speed	Wind character	Altim. setting	Remarks
SA	1455	E40 BKN 80 OVC	7				75	66	27	10		006	
SP	1515	E40 BKN 80 OVC	3		TRW				27	10		006	
SP	1530	X E40 BKN 80 OVC	2		TRW				24	10		004	
SA	1555	-X E50 OVC	3		RW F		70	67	24	10		004	
SP	1640	X E50 OVC	5		RW F				24	10		005	
SA	1655	-X E50 OVC	5		F		70	67	24	10		005	
SA	1755	-X E60 BKN 100 OVC	5		F		70	67	24	10		004	
SA	1855	X 25 SCT E 100 OVC	5		F		70	67	23	08		004	
SA	1955	-X E25 BKN 100 OVC	5		F		70	67	23	08		003	
SA	2055	-X E25 BKN 100 OVC	5		F		70	67	23	10		003	
SA	2155	-X E20 BKN 100 OVC	4		F		70	67	23	10		003	
SA	2255	-X 10 SCT E20 BKN 100 OVC	5		F		70	67	24	08		004	
SA	2355	-X 8 SCT E20 BKN 100 OVC	4		F		70	68	22	05		004	
SP	0025	M7 OVC	3		F				24	06		003	
SA	0055	-X M8 OVC	3		F		69	67	25	04		003	
SA	0155	-X M8 OVC	3		F		69	67	25	04		003	
SA	0255	-X M8 OVC	3		F		69	67	25	04		003	
SP	0335	W2X	1		F				00	00		002	R23 VR 60+
SA	0355	W2X	1		F		70	68	00	00		002	R23 VR 60+
SA	0455	W2X	1/2		F		69	67	00	00		003	R23 VR 30
SA	0555	W2X	1/2		F		69	68	00	00		003	R23 VR 30
SP	0636	W3X	1		F				00	00		004	R23 VR 60+
SA	0655	W3X	1		F		69	67	00	00		003	R23 VR 60+
SP	0738	W4X	2		F				00	00		004	
SA	0755	W5X	2		F		70	69	00	00		004	
SP	0809	5 SCT M30 OVC	2		F				00	00		004	SVN BMLY VSBL
SA	0855	8 SCT M30 OVC	2		F		72	70	00	00		003	BIN OVC

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY
Midnight to Midnight

Figure A8. Surface Weather Observations Taken at the FAA Tower at Otis AFB

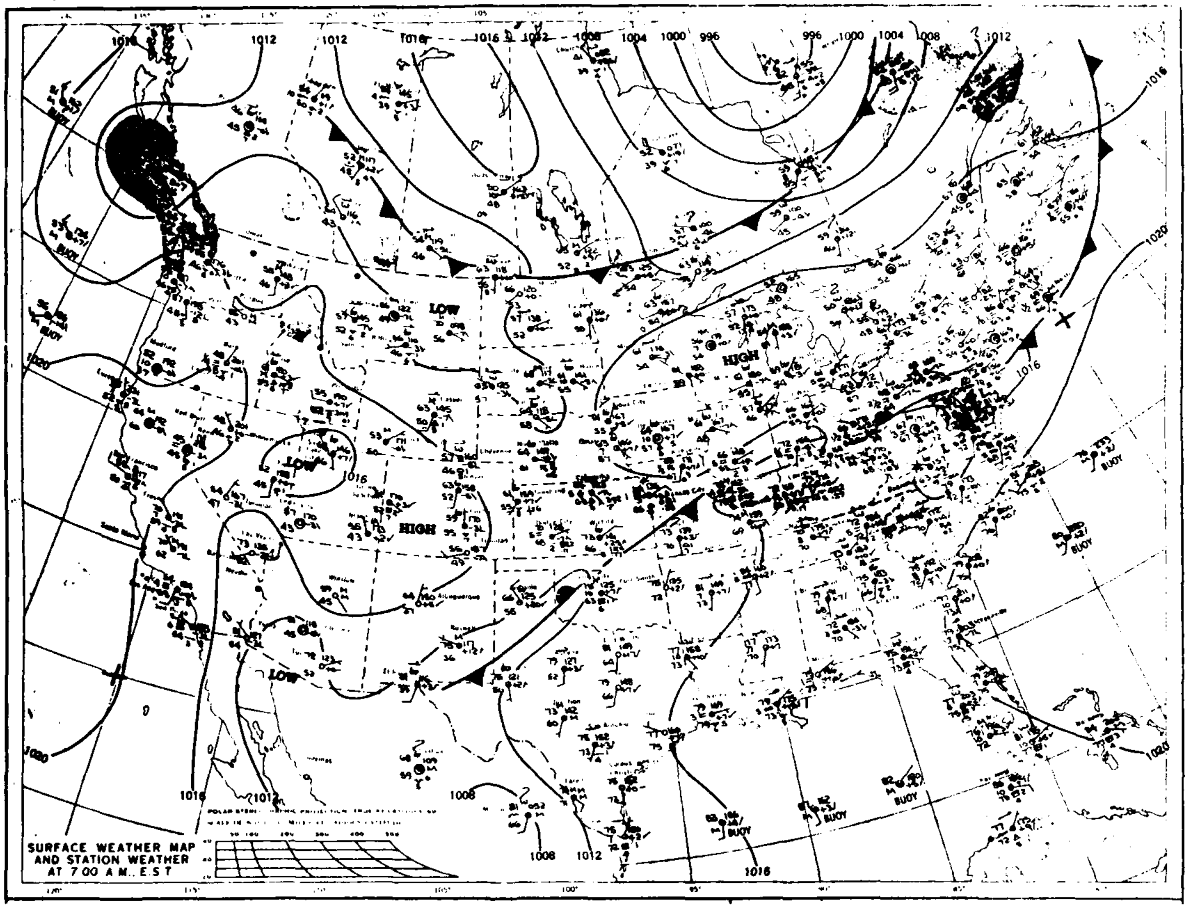


Figure A9. Surface Weather Map for 0800 EDT on 3 July 1980

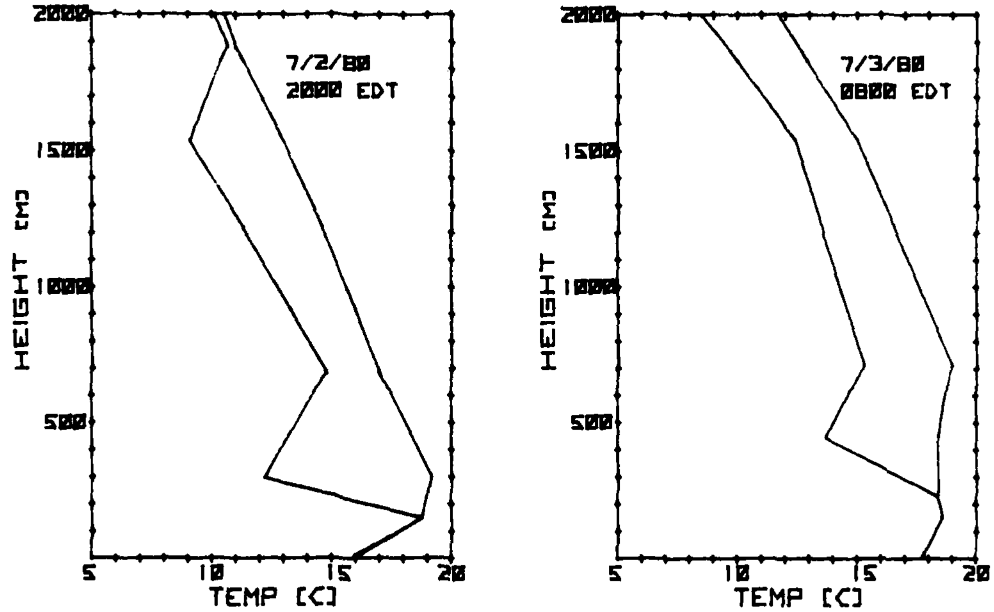


Figure A10. Chatham Radiosonde Soundings Before and After the Fog Episode

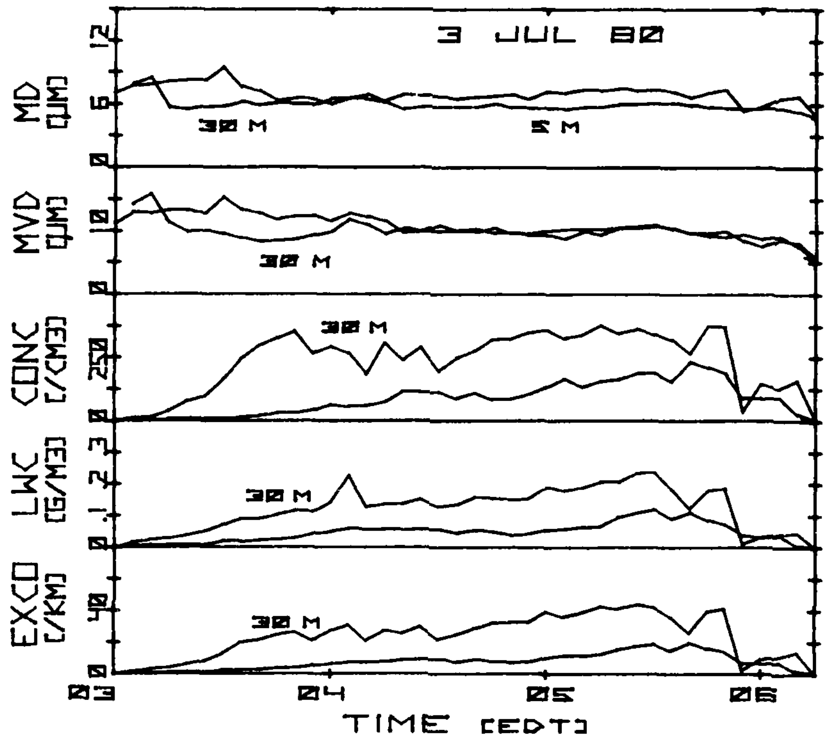


Figure A11. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

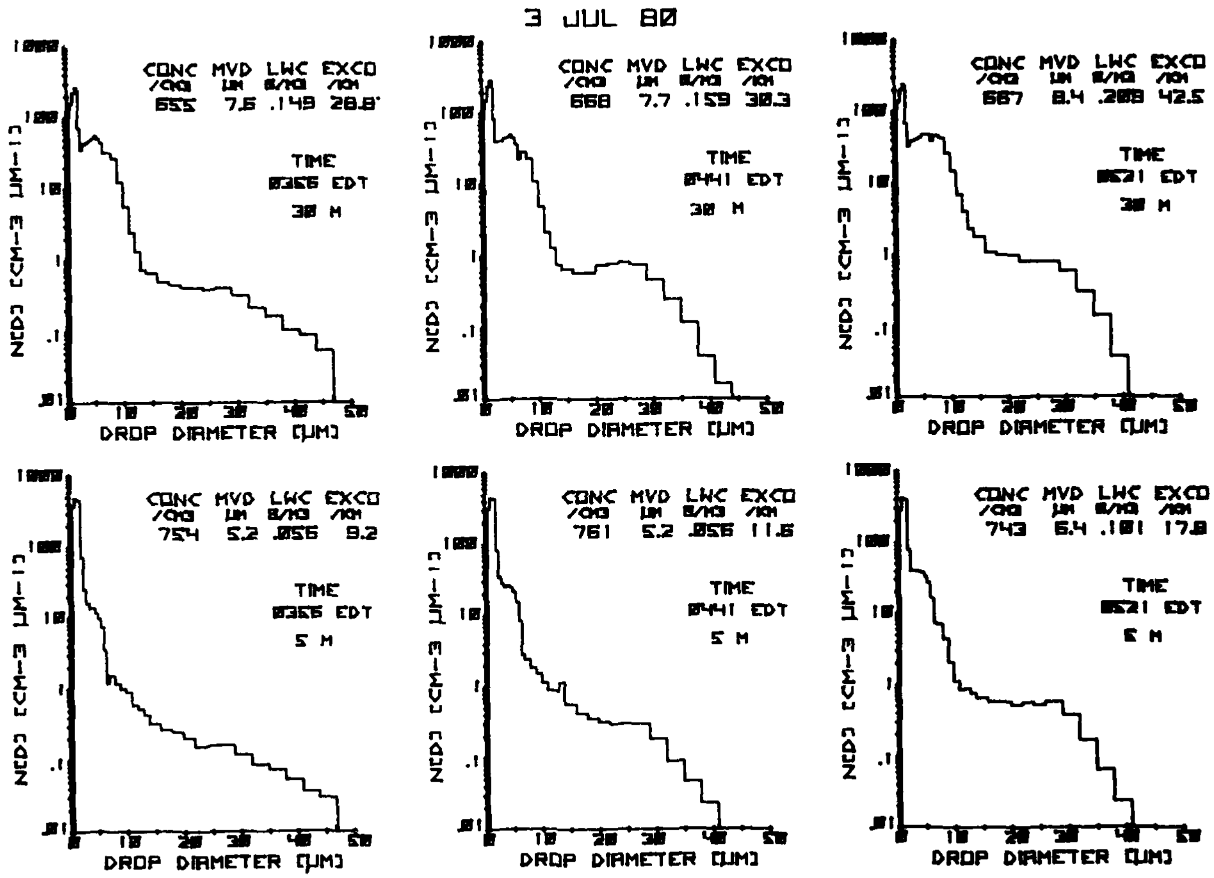


Figure A12. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

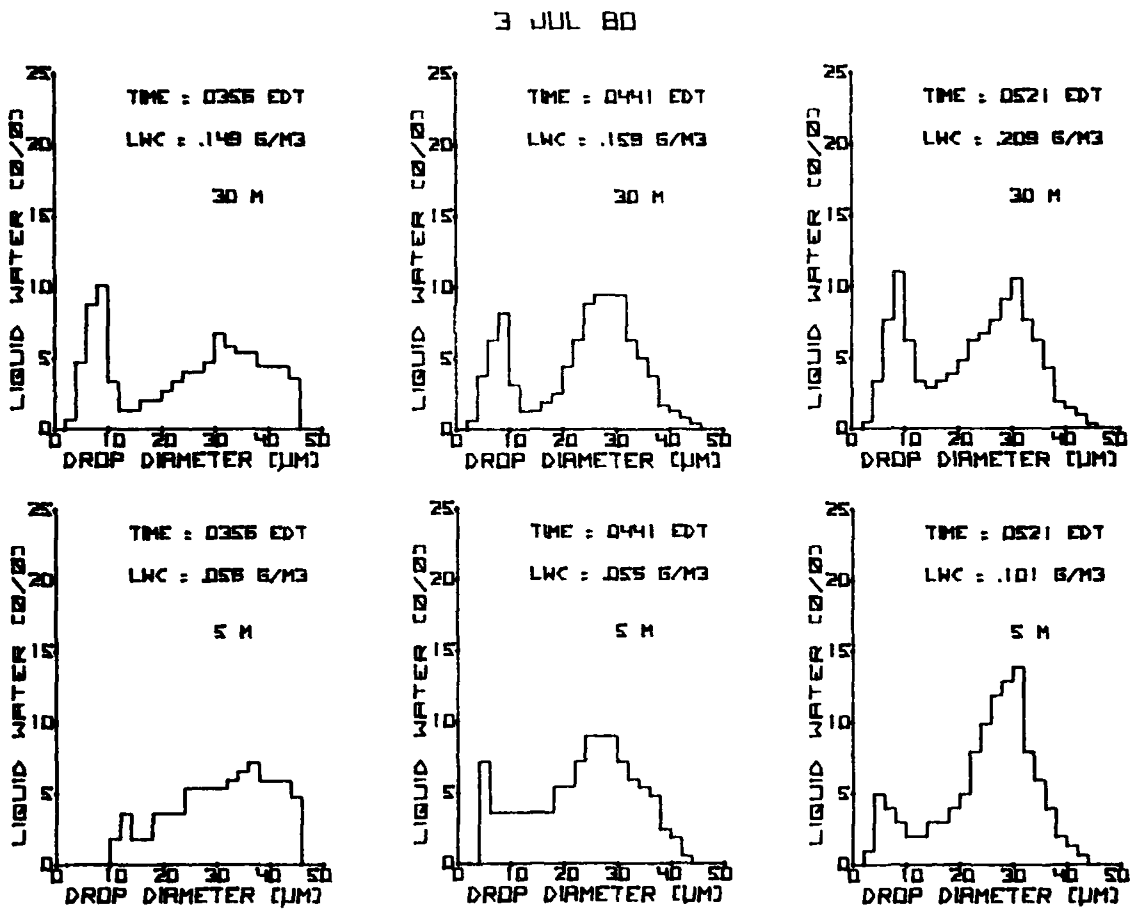


Figure A13. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

2-3 JUL 80

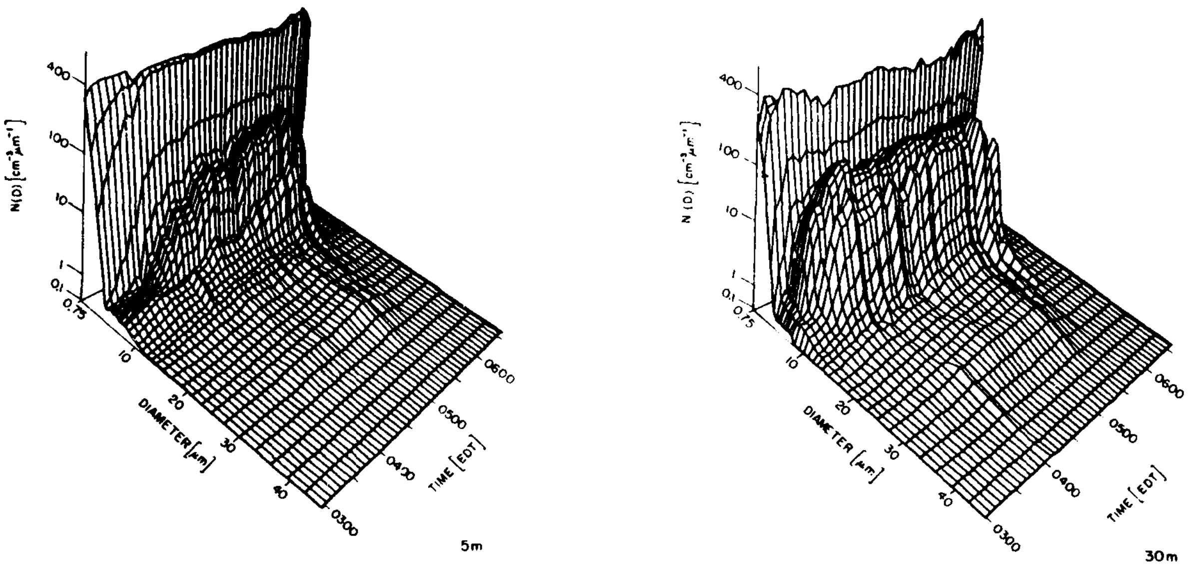


Figure A14. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

Case 3: 3-4 July 1980
(see Figures A15 through A21)

Time Period (vis < 1 mi)	2045-0700 EDT
Duration	10 h 15 min
Wind Direction	230^{o}
Wind Speed	3-7 knots
Temperature	$70^{o}F$
Estimated Depth	120 m
Comments	Fog preceded by low stratus and rain. Drizzle observed in fog. Stratus broke up about 0830.

WPL-10C (12-77)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SURFACE WEATHER OBSERVATIONS
(Abridged for use at designated Civil Stations)

OTIS TOWER
7/3–4/80

To convert LST to GMT ADD ____ hrs | Time in Column 2 is: GMT ____ LDT X

TYPE (1)	TIME (2)	SKY AND CEILING (Hundreds of feet) (3)	VISIBILITY (miles) SURFACE (4)	VISIBILITY (miles) TOWER (4a)	WEATHER AND OBSTRUCTIONS TO VISION (5)	SEA LEVEL PRESS (mb) (6)	TEMP (°F) (7)	DEW PT (°F) (8)	WIND DIREC-TION (9)	WIND SPEED (kts) (10)	WIND CHAR-ACTER (11)	ALTIM SETTING (ins.) (12)	REMARKS AND SUPPLEMENTAL (13)
SP	1822	–X M1 OVC	3/4		R-F				00	00		993	R23 VR 50
SA	1855	–X M1 OVC	3/4		R-F		71	71	00	00		993	R23 VR 60+
SP	1936	–X M1 OVC	1/4		F				21	06		994	R23 VR 30
SA	1955	–X M1 OVC	1/4		F		70	69	22	06		994	R23 VR 32
SP	2017	–X M1 OVC	3/4		R-F				23	05		993	R23 VR 38
SP	2026	–X M2 BKN 4 OVC	1		R-F				22	06		993	R23 VR 38
SP	2037	–X M2 OVC	3/4		R-F				23	04		993	R23 VR 34
SP	2049	W1X	1/4		R-F				21	08		993	R23 VR -10
SA	2055	W0X	1/16		R-F		70	17	22	06		993	R23 VR 10-
SA	2155	W0X	1/4		L-F		70	17	25	06			
SA	2255	W0X	1/4		L-F		70	17	25	04		992	R23 VR 10
SA	2355	W0X	1/4		L-F		70	17	23	04		990	R23 VR 10
SA	0055	W0X	1/4		L-F		70	69	23	06		989	
SA	0155	W0X	1/4		L-F		70	69	23	04		988	
SA	0255	W0X	1/4		L-F		70	69	22	06		988	
SA	0355	W0X	1/4		L-F		69	69	24	06		988	
SA	0455	W0X	1/4		L-F		69	69	23	04		986	
SA	0555	W0X	1/8		L-F		69	69	00	00		990	
SA	0655	W0X	1/8		F		70	69	00	00		992	
SA	0755	W1X	1/4		F		71	70	00	00		992	
SP	0829	–X M4 BKN 30 OVC	2		F				00	00		991	
SA	0855	–X 10 SCT	2		FH		74	72	34	08		992	
SP	0950	–X 20 SCT	3		FH				36	08		990	
SA	0955	–X 20 SCT	3		H		78	70	36	08		990	
SP	1030	60 SCT	6						03	05		992	
SA	1055	60 SCT	8				80	66	03	06		992	
SA	1155	200 SCT	10				82	63	06	08		993	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY (Midnight to Midnight)

Figure A15. Surface Weather Observations Taken at the FAA Tower at Otis AFB

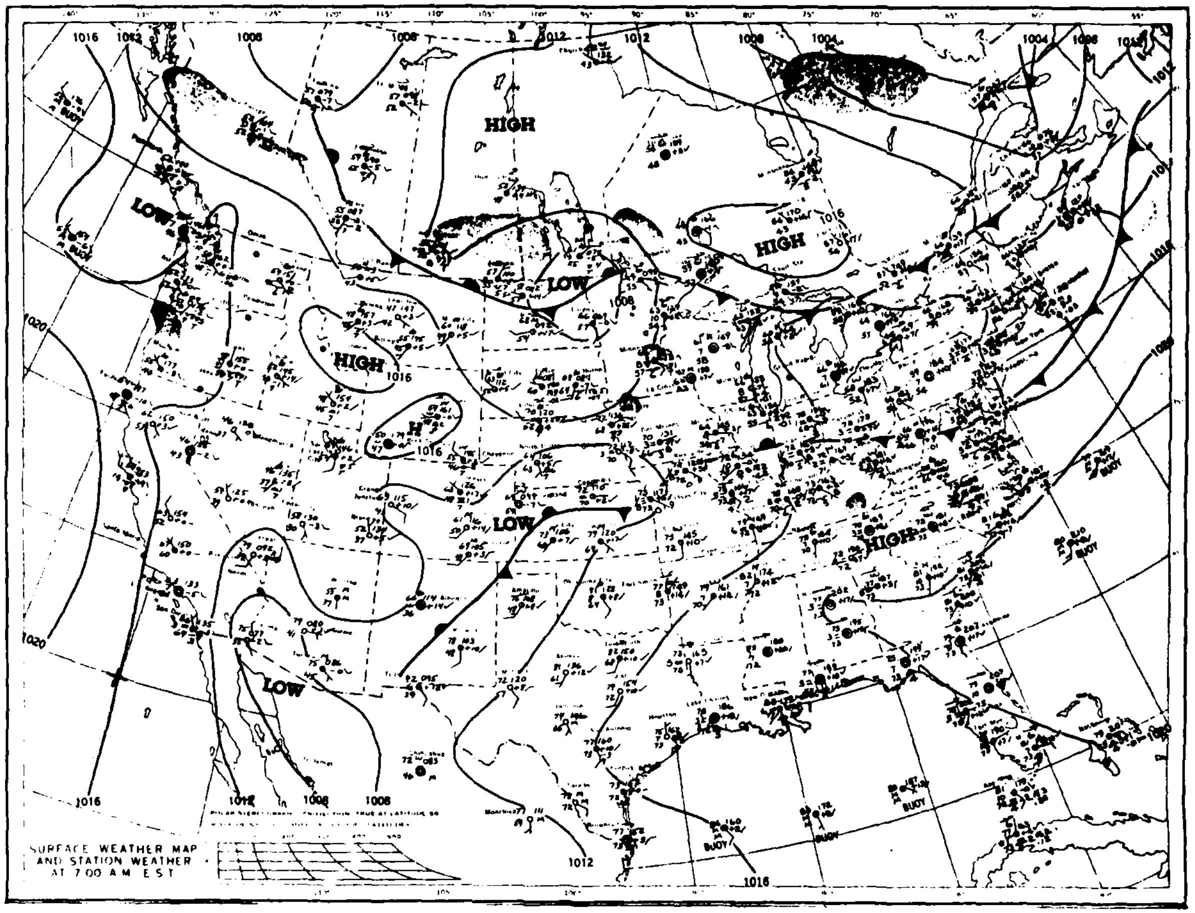


Figure A16. Surface Weather Map for 0800 EDT on 4 July 1980

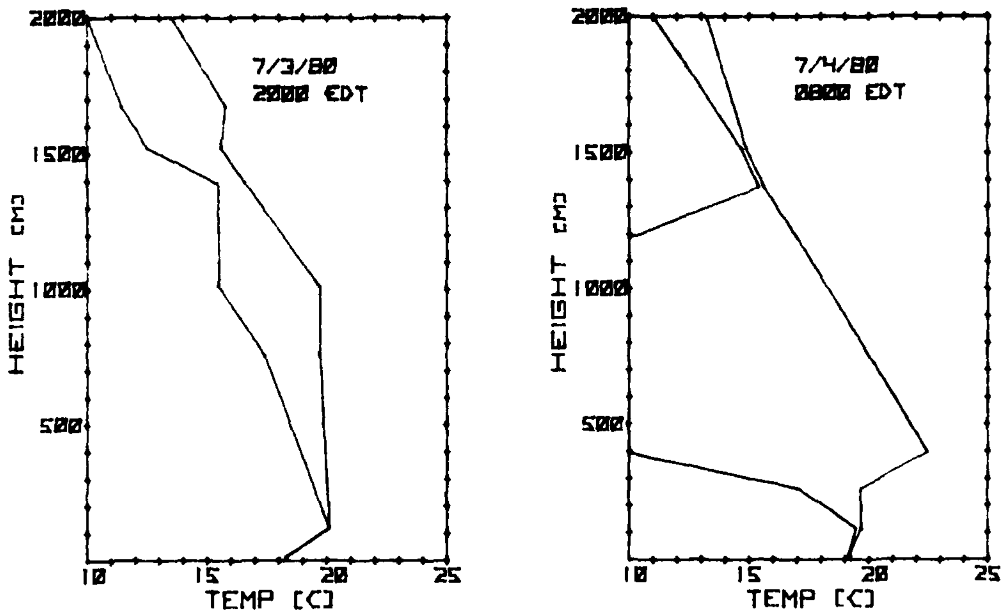


Figure A17. Chatham Radiosonde Soundings Before and After the Fog Episode

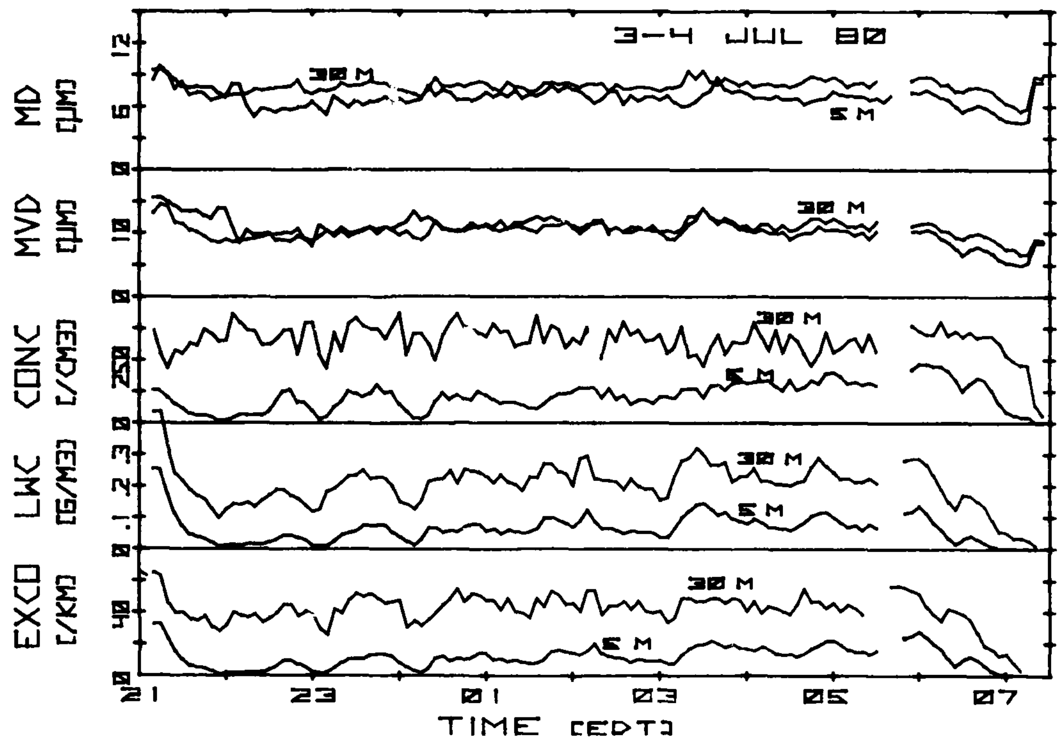


Figure A18. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

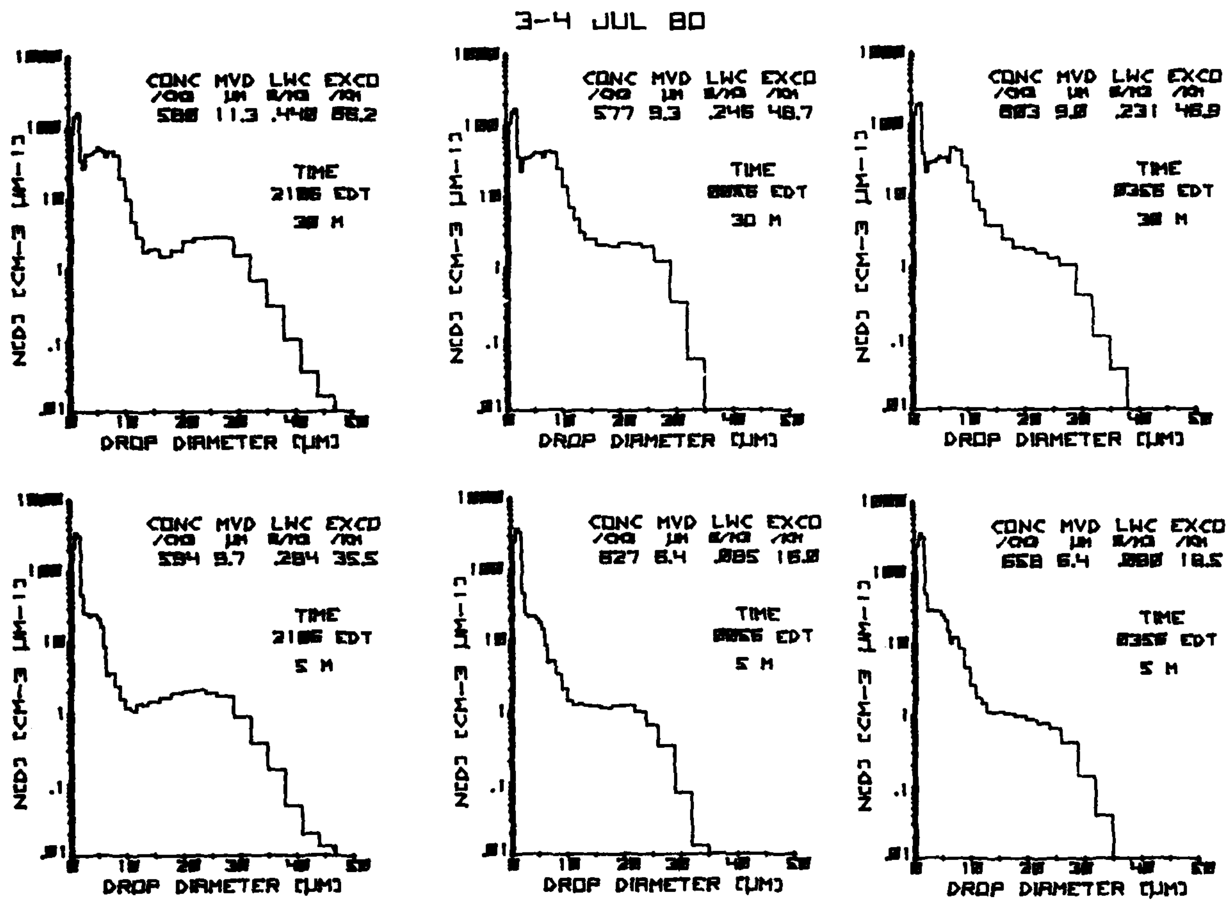


Figure A19. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level

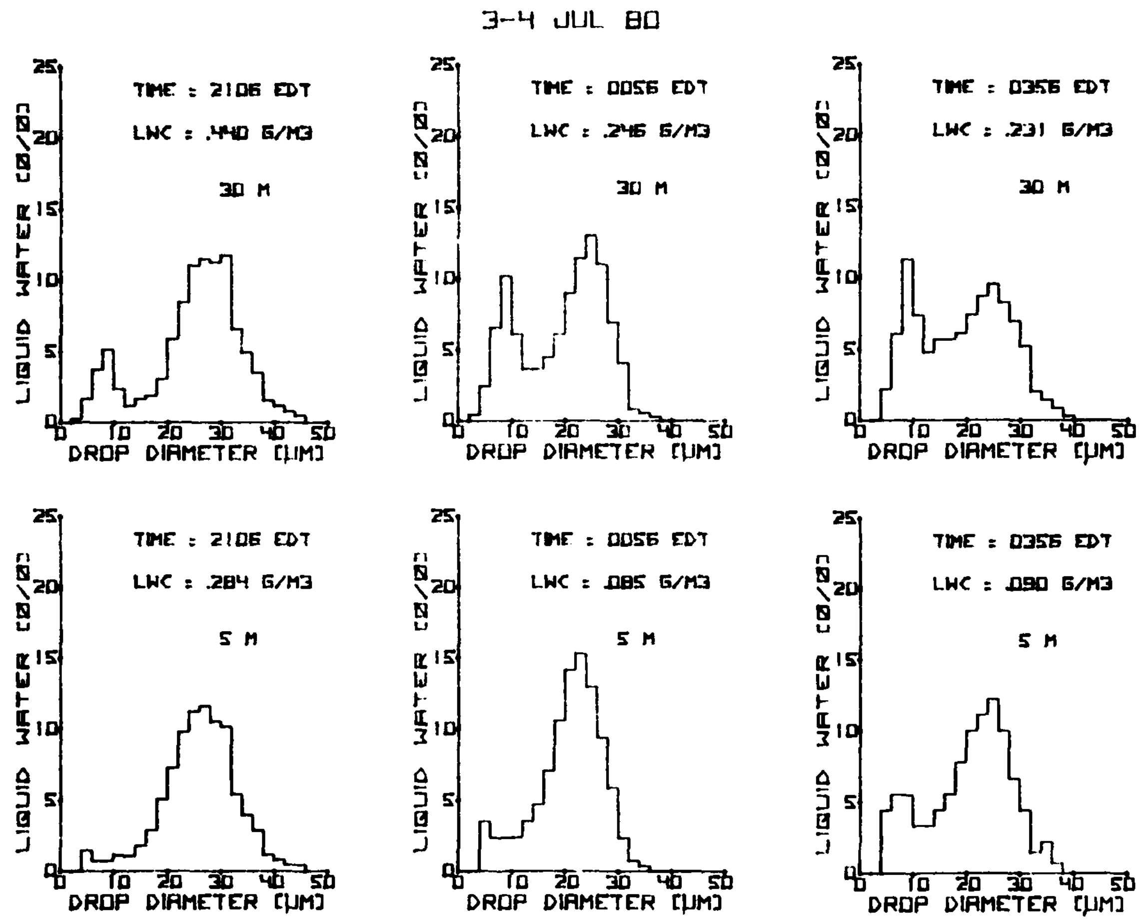


Figure A20. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m Level

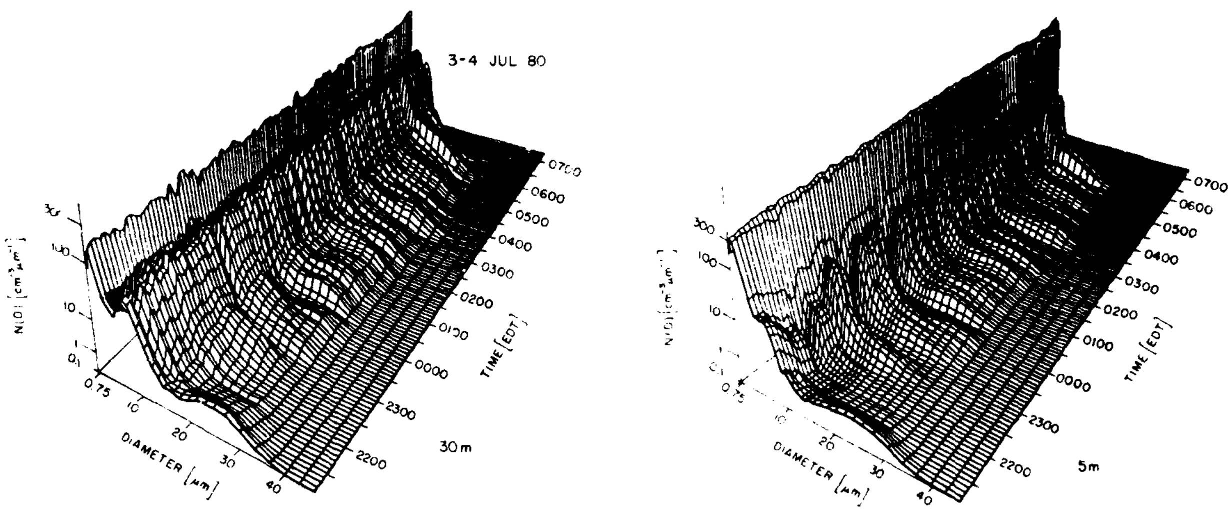


Figure A21. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m Level

Case 4: 10-11 July 1980
(see Figures A22 through A28)

Time Period (vis < 1 mi)	2055-0415 EDT
Duration	7 h 20 min
Wind Direction	180^{o}
Wind Speed	5 knots
Temperature	63^{o}-68^{o}F
Estimated Depth	150 m
Comments	Visibility quite variable throughout the fog duration. Fog formed less than one hour after stratus formed. Fog lifted after sunrise and stratus layer broke up about 0845.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SURFACE WEATHER OBSERVATIONS

OTIS TOWER
7/10-11/80

Time in Column 2 is: GMT____ LDT _X_

TYPE (1)	TIME (2)	SKY AND CEILING (3)	VISIBILITY SURFACE (4)	VISIBILITY TOWER (4a)	WEATHER AND OBSTRUCTIONS TO VISION (5)	SEA LEVEL PRESS (6)	TEMP (°F) (7)	DEW PT (°F) (8)	WIND DIRECTION (9)	WIND SPEED (10)	WIND CHARACTER (11)	ALTIMETER SETTING (12)	REMARKS AND SUPPLEMENTAL (13)
SA	1755	−X 30 SCT	6		H	7	77	69	18	06		983	
SA	1855	−X 30 SCT	6		H		74	68	18	05		983	
SA	1955	−X M4 BKN	3		FH		71	69	18	04		984	
SP	2022	M1 OVC	1/2		F				18	04		984	
SA	2055	W1X	1/8		F		68	68	18	04		984	
SA	2155	W1X	1/4		F		67	67	20	06		985	
SA	2255	W1X	3/4		F		66	66	18	04		985	
SA	2355	W1X	3/4		F		66	65	16	06		983	R23VR40
SP	0020	W1X	1/2		F				17	06		983	R23VR16
SA	0055	W1X	1/2		F		66	65	18	06		983	R23VR18
SA	0155	W1X	1/2		F		65	63	18	04		983	R23VR32
SA	0255	W1X	1/4		F		65	64	21	06		982	R23VR18
SA	0355	W1X	1/2		F		65	64	21	06		980	R23VR34
SA	0455	W2X	3/4		F		63	63	21	05		978	R23VR50
SA	0555	W2X	1		F		63	63	29	06		980	R23VR60+
SA	0655	W2X	1		F		63	63	24	06		980	R23VR60+
SP	0715	−X M4 OVC	1 1/2		F				24	06		978	
SP	0740	−X M4 OVC	2		F				24	06		979	
SA	0755	−X M4 OVC	2		F		66	63	20	06		979	
SP	0838	−X M7 OVC	3		F				27	06		978	BINOVC
SA	0855	7 SCT	5		F		69	66	25	04		980	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY

Figure A22. Surface Weather Observations Taken at the FAA Tower at Otis AFB

FRIDAY, JULY 11, 1980

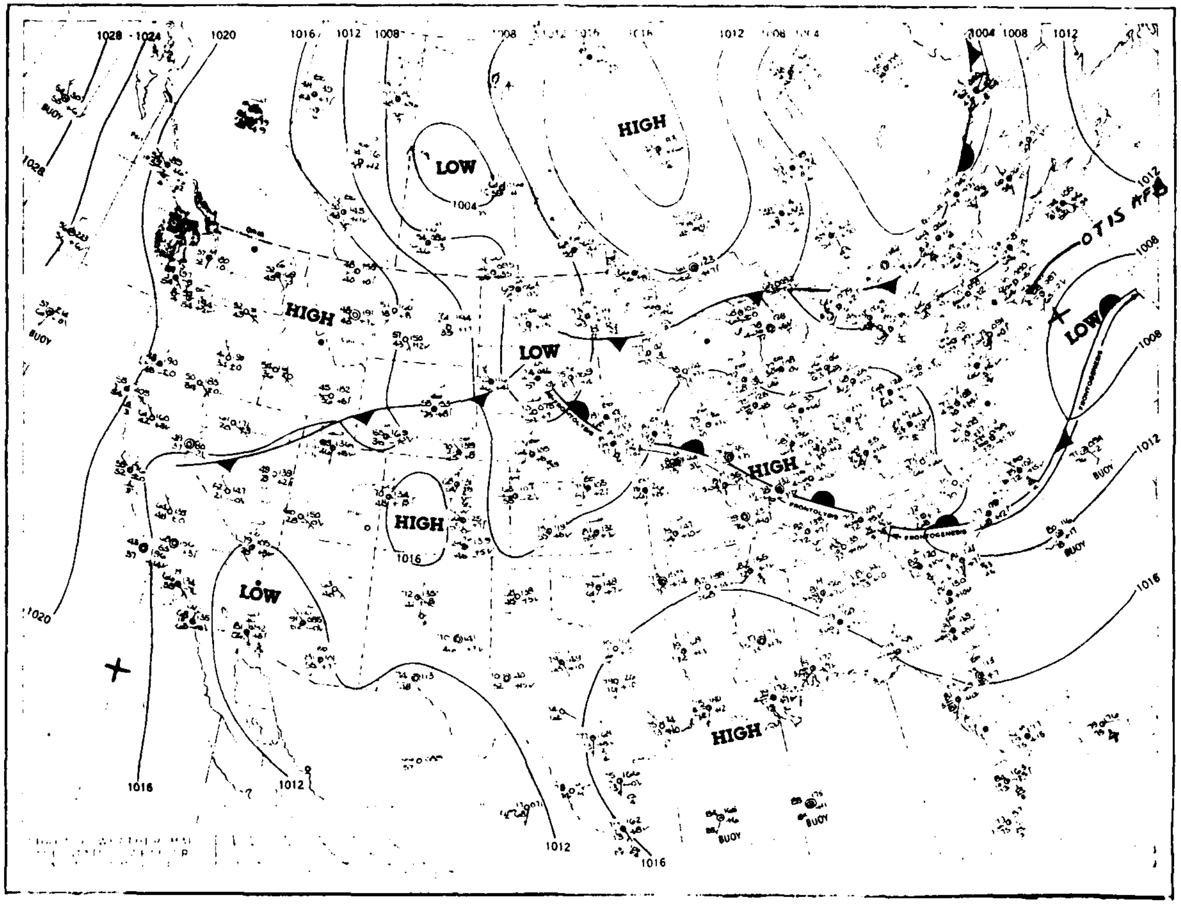


Figure A23. Surface Weather Map for 0800 EDT on 11 July 1980

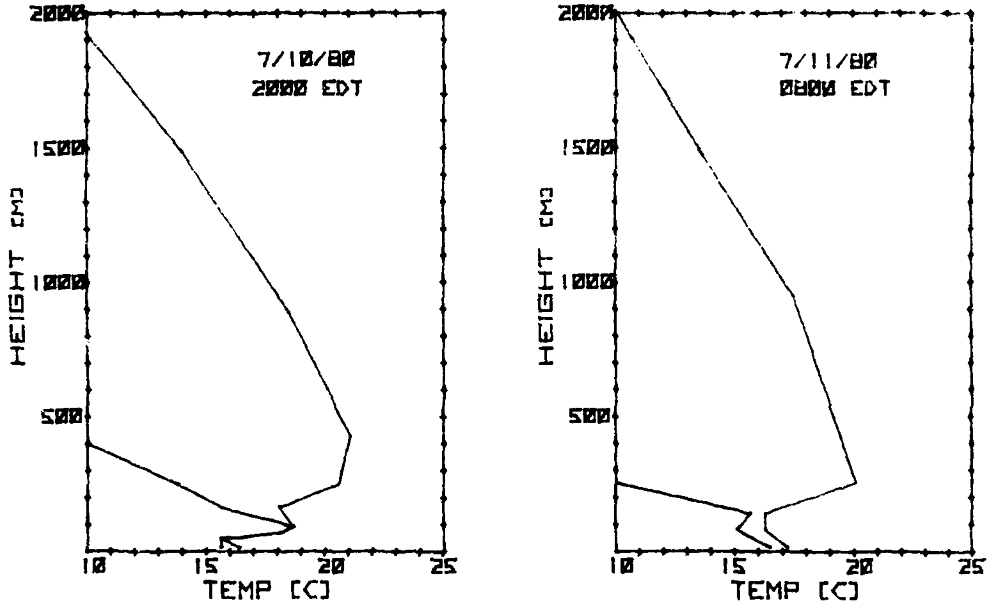


Figure A24. Chatham Radiosonde Soundings Before and After the Fog Episode

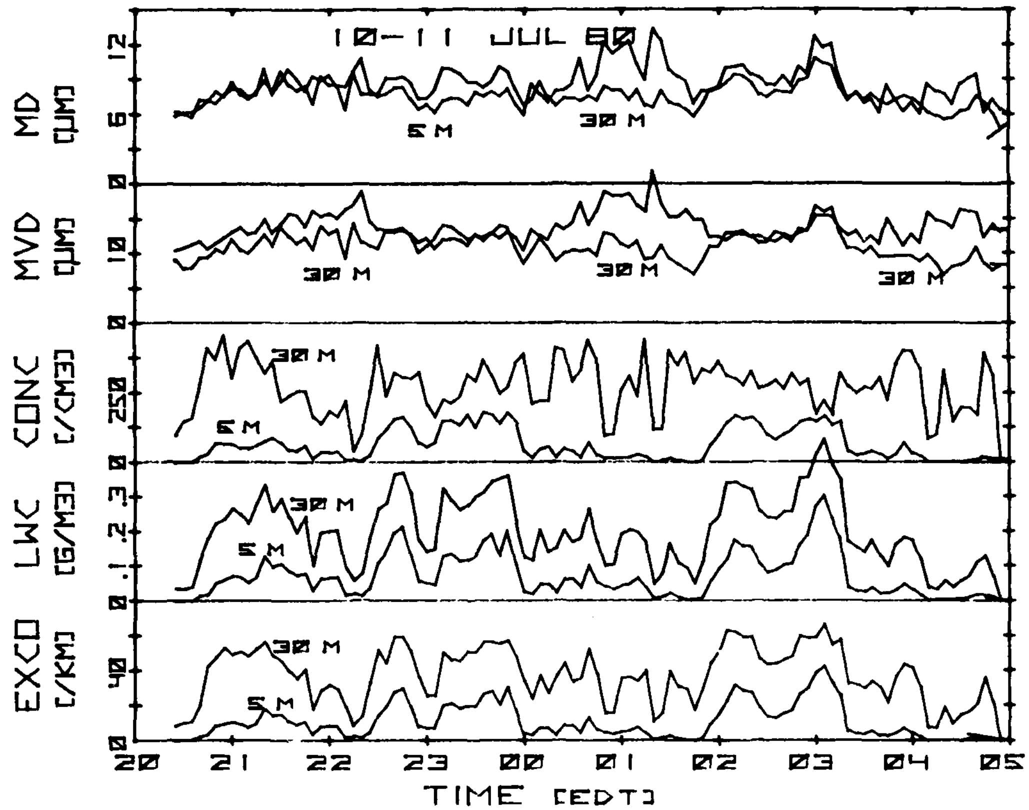


Figure A25. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5 and 47 μm diameter

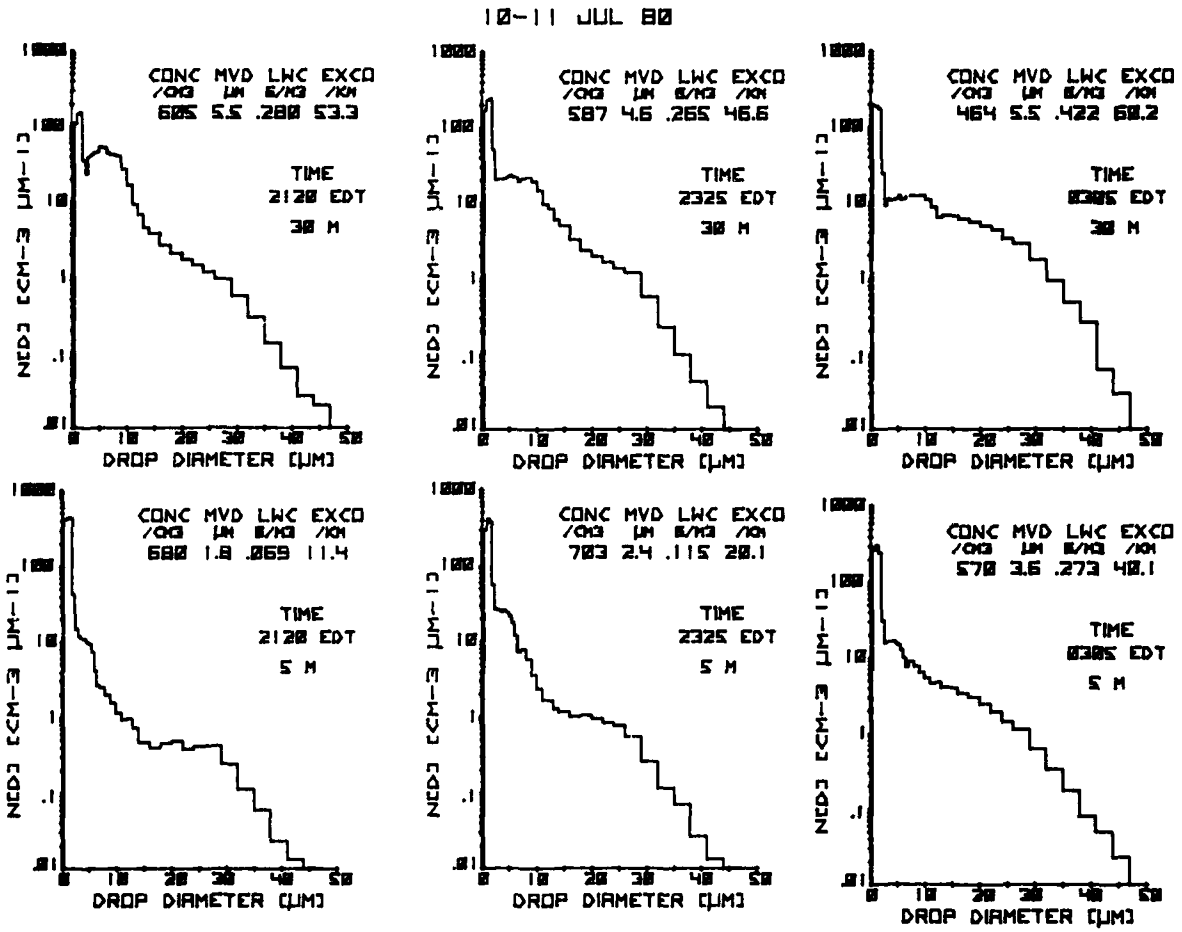


Figure A26. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

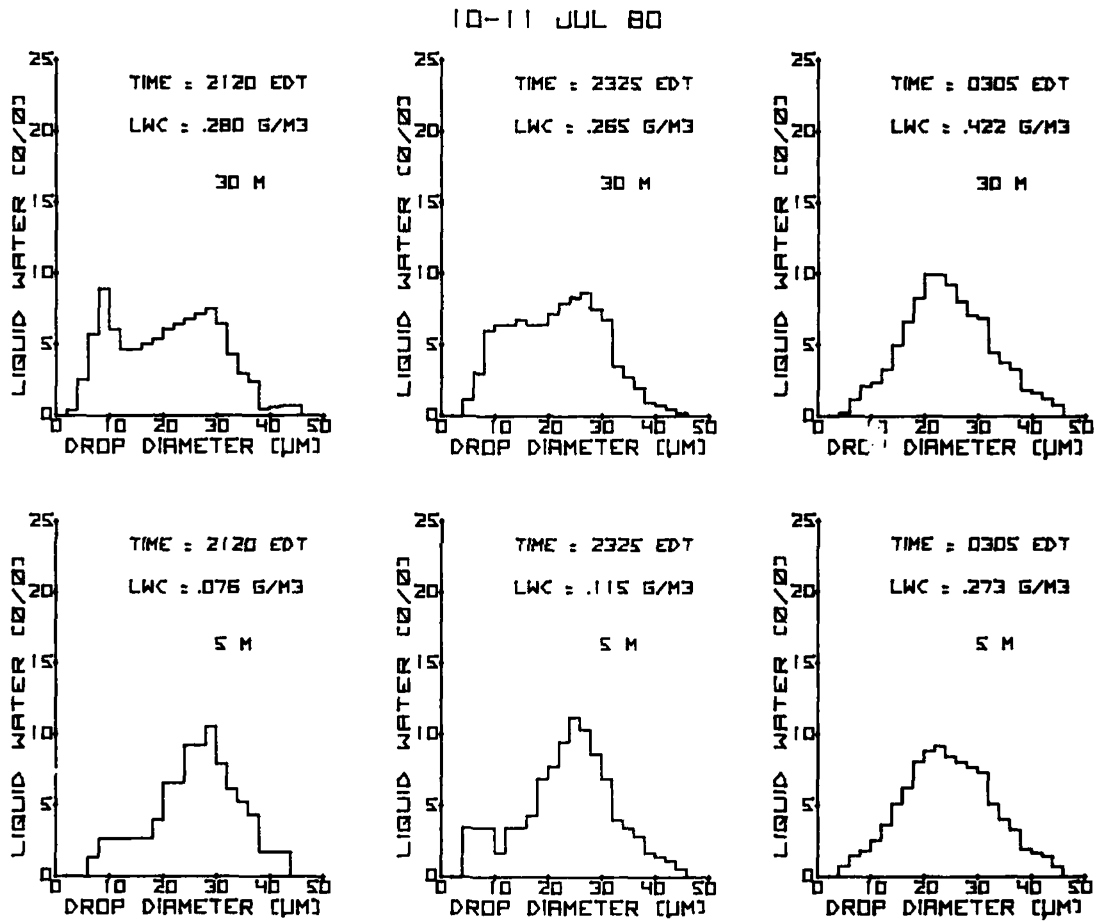


Figure A27. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

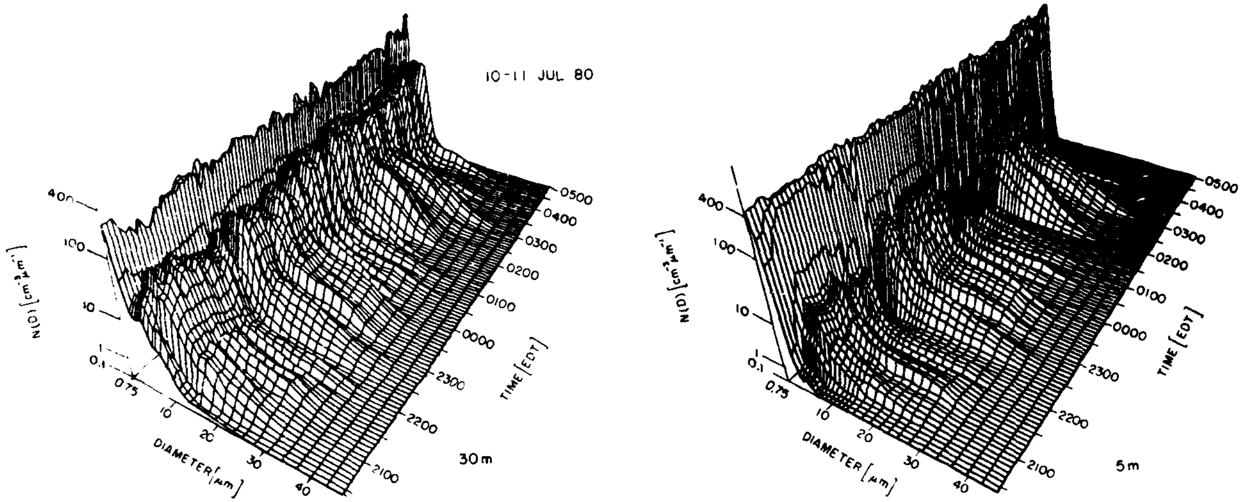


Figure A28. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

Case 5: 11-12 July 1980
(see Figures A29 through A35)

Time Period (vis < 1 mi)	2200-0420 EDT
Duration	6 h 20 min
Wind Direction	220^{o}
Wind Speed	4-6 knots
Temperature	$67-69^{o}F$
Estimated Depth	200-400 m
Comments	Fog preceded for several hours by low stratus. Fog lifted after sunrise and stratus broke up about 0700.

U.S. DEPARTMENT OF COMMERCE

SURFACE WEATHER OBSERVATIONS

OTIS TOWER
7/11-12/80

Time in Column 2 is GMT ___ LDT X

Type	Time	Sky and Ceiling	Visibility Surface	Visibility Tower	Weather and Obstructions to Vision	Sea Level Press	Temp	Dew Pt	Wind Direction	Wind Speed	Wind Character	Altimeter Setting	Remarks and Supplemental
SA	1155	200 BKN	7				77	66	22	04		977	
SA	1255	−X 200 - BKN	6		FH		77	65	23	10		976	
SA	1355	−X 40 SCT 150 - SCT	6		FH		78	66	23	10		974	
SA	1455	−X 40 SCT 150 - SCT	6		FH		78	66	21	08		972	
SA	1555	−X 150 SCT	5		FH		77	66	20	10		971	FOG BANKS
SA	1655	−X 150 SCT	3		FH		75	66	20	10		969	FOG BANKS
SP	1733	−X E80 BKN	2		F				23	10		969	FOG BANK W
SA	1755	M6 OVC	1 1/2		F		70	67	24	12		969	
SA	1855	M5 OVC	1 1/2		F		69	67	22	12		967	
SA	1955	M4 OVC	1 1/2		F		69	66	25	12		967	
SA	2055	M2 OVC	1 1/2		F		68	66	25	10		968	
SA	2155	M1 OVC	1		F		68	66	26	12		969	R23VR40
SA	2255	W1X	1/2		F		67	67	28	07		970	R23VR22
SA	2355	W1X	1/2		F		67	67	25	08		965	R23VR28
SA	0055	W1X	1/4		F		67	67	22	09		964	R23VR20
SA	0155	W1X	1/4		F		68	67	22	10		964	R23VR22
SA	0255	W0X	1/4		F		68	68	21	12		962	R23VR14
SA	0355	W1X	1/2		F		69	68	23	10		960	R23VR24
SA	0455	W2X	3/4		F		69	68	24	09		960	R23VR34
SA	0555	−X 174 OVC	1		F		69	68	28	07		964	R23VR36 BINOVC
SA	0655	−X 174 BKN	1 1/2		F		69	68	35	08		965	
SP	0711	−X 5 SCT 150 SCT	3		F				35	10		966	
SA	0755	20 SCT 150 BKN	10				71	66	36	06		967	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY

Figure A29. Surface Weather Observations Taken at the FAA Tower at Otis AFB

SATURDAY, JULY 12, 1980

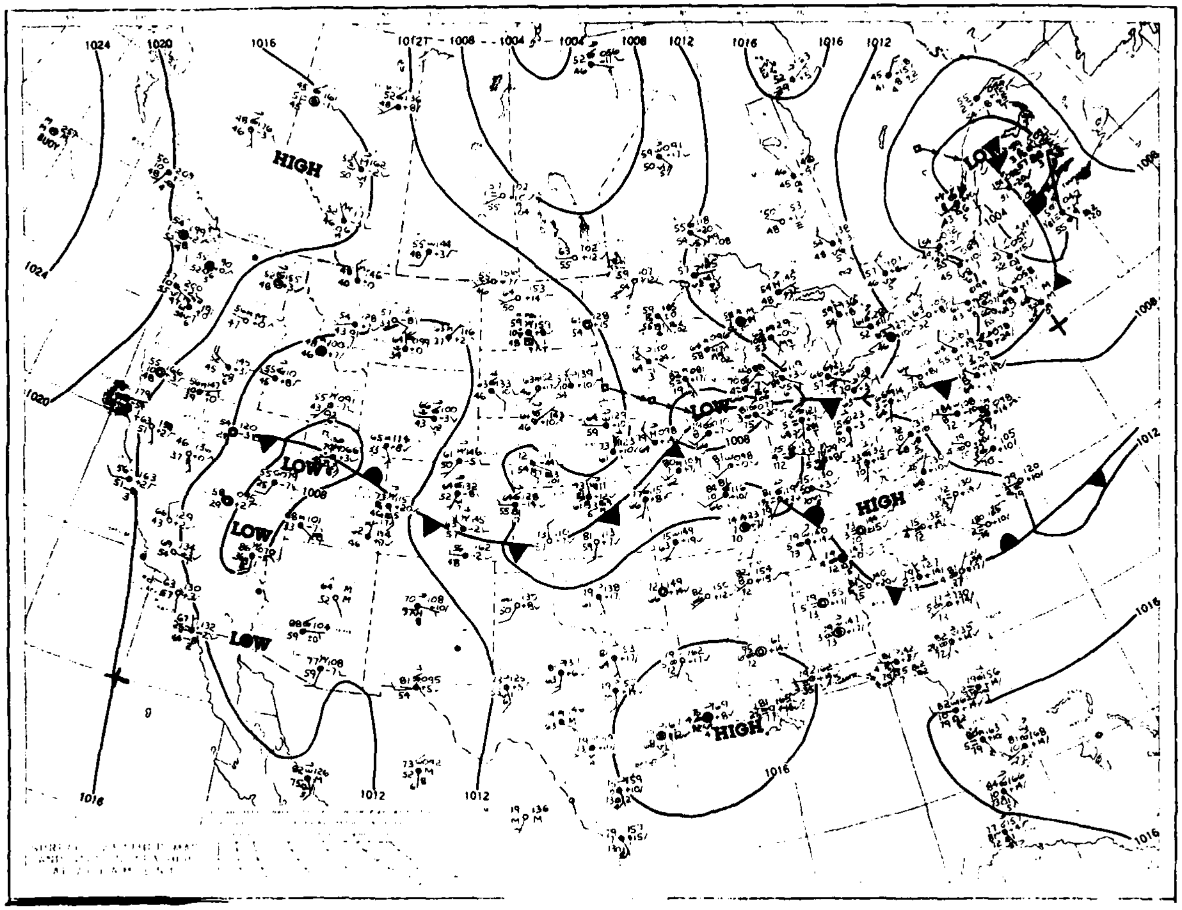


Figure A30. Surface Weather Map for 0800 EDT on 12 July 1980

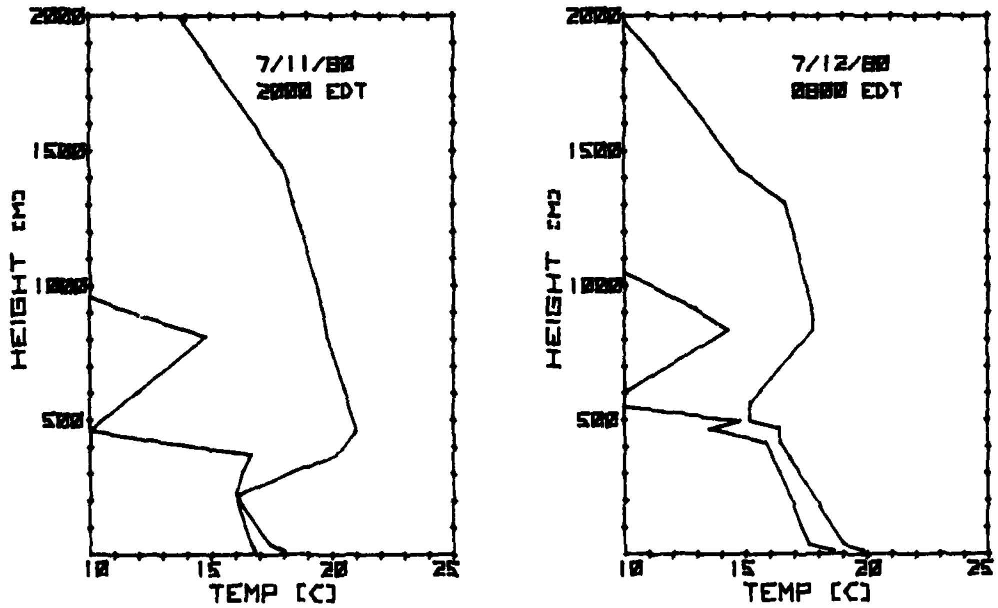


Figure A31. Chatham Radiosonde Sounding Before and After the Fog Episode

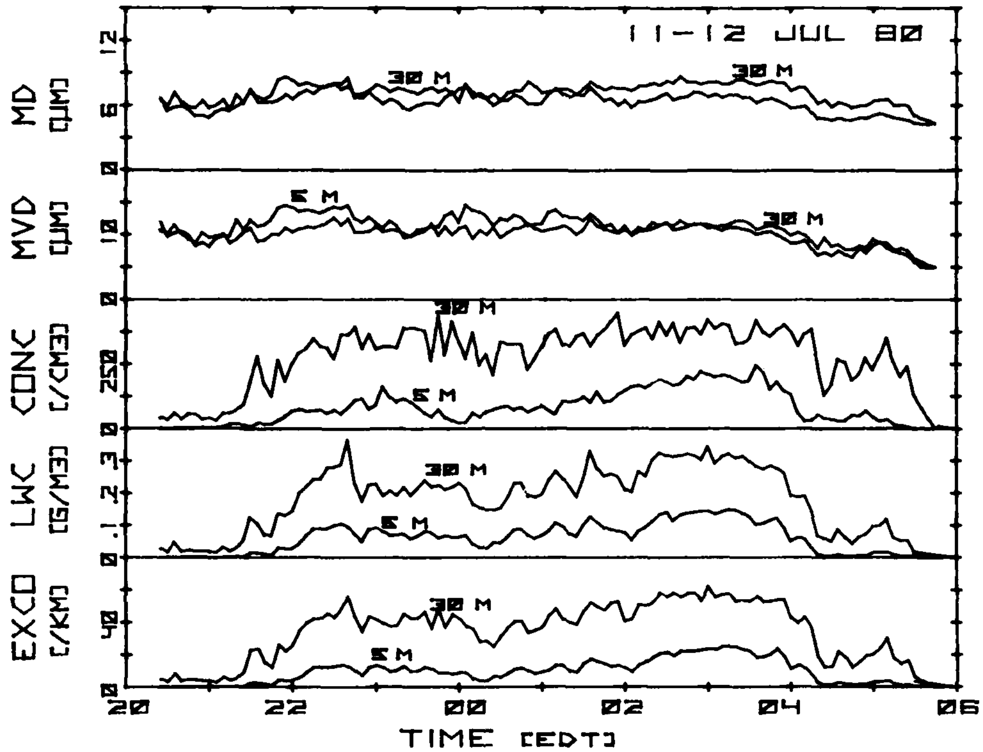


Figure A32. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

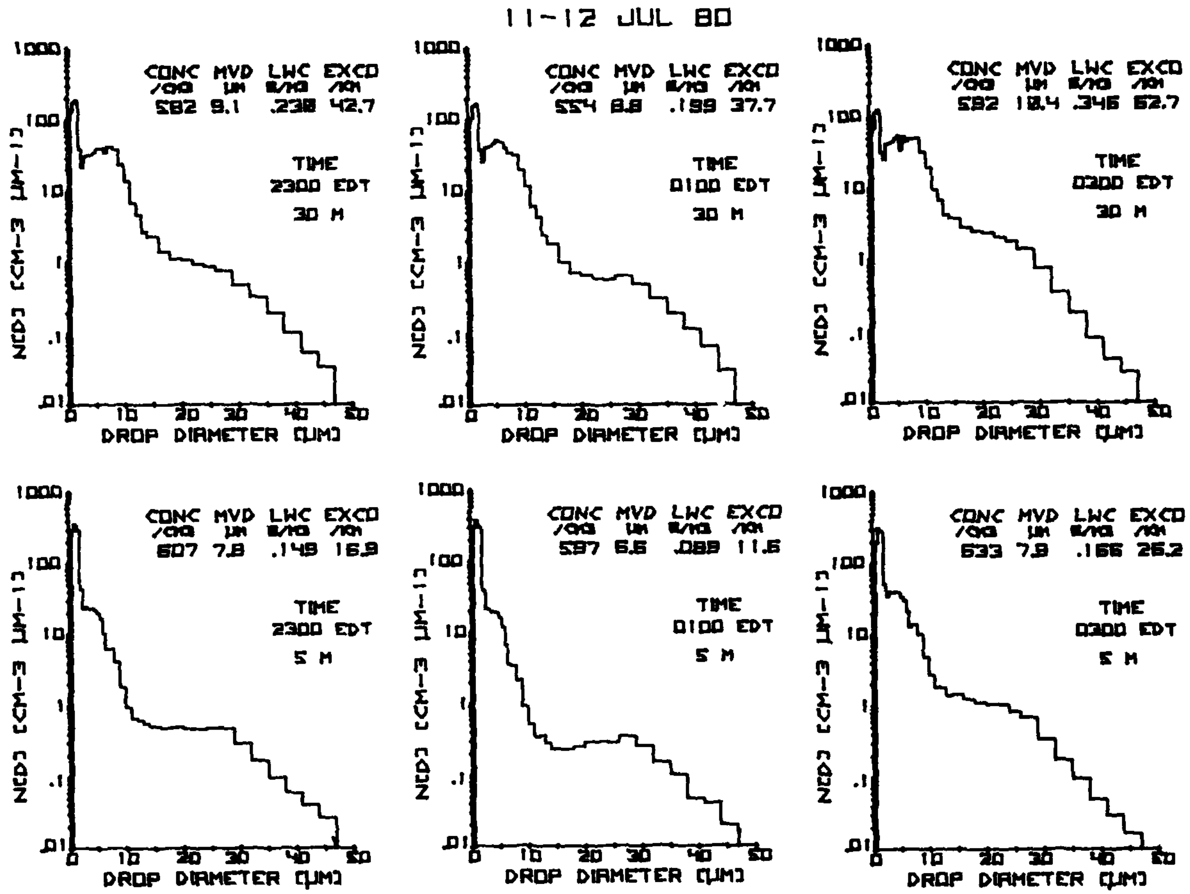


Figure A33. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

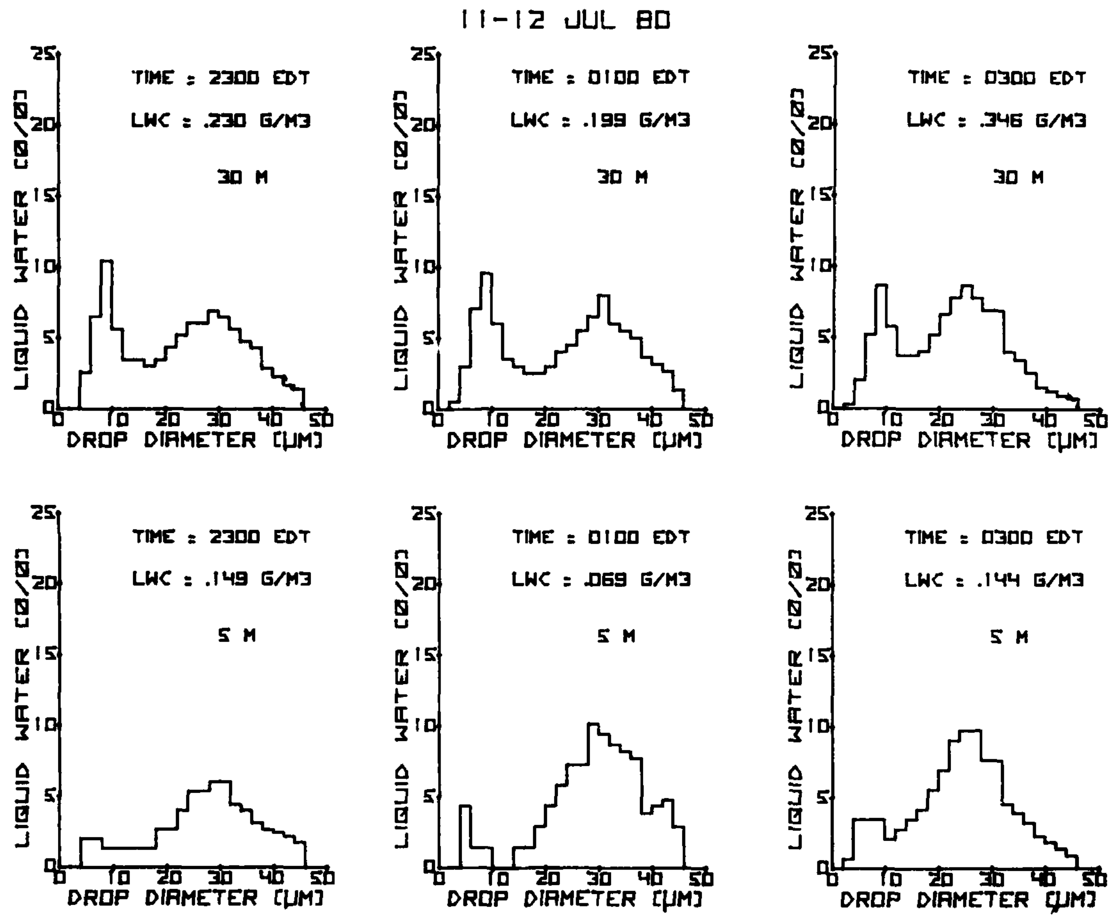


Figure A34. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

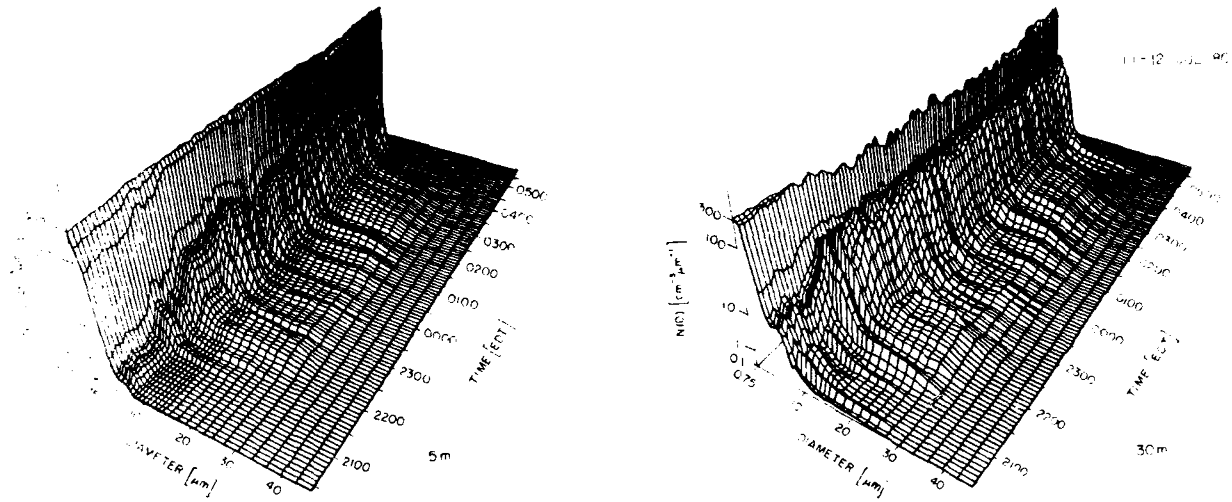


Figure A35. **Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels**

Case 6: 17-18 July 1980
(see Figures A36 through A42)

Time Period (vis < 1 mi)	0000-0355 EDT
Duration	3 h 55 min
Wind Direction	260°
Wind Speed	10 knots
Temperature	$74^{\circ}F$
Estimated Depth	100 m
Comments	Fog preceded for several hours by low stratus and winds of 12 to 28 knots. Cold front passed through area at about 0355, clearing out fog.

SURFACE WEATHER OBSERVATIONS

OTIS TOWER

7/17-18/80

Time in Column 2 is: GMT ____ LDT X

Type	Time	Sky and Ceiling (Hundreds of feet)	Visibility Surface	Visibility Tower	Weather and Obstructions to Vision	Sea Level Press.	Temp	Dew Pt	Wind Direction	Wind Speed	Wind Character	Altim Setting	Remarks
SA	1665	–X 30 SCT E100 BKN	3		TFH		80	74	23	10G	22	973	T W MOVG E
SP	1715	E30 BKN 100 OVC	2		TRWF				23	10G	22	973	T OVHD MOVG E
SA	1755	E30 BKN 100 BKN	3		FH		75	74	23	10G	20	973	TE MOVD E
SA	1855	M50 BKN 100 OVC	3		F		75	74	25	14G	22	974	
SA	1955	M50 BKN 100 BKN	3		F		76	74	25	12		974	
SP	2020	M4 OVC	2		F				24	12		974	
SA	2055	M1 OVC	1		F		74	74	24	18		976	
SP	2135	M4 OVC	3		F				24	12		976	
SA	2155	M5 OVC	3		F		74	74	25	12		977	
SA	2255	M5 OVC	3		F		74	74	25	12		977	
SA	2355	–X M3 OVC	3		FH		74	74	25	15		977	
SP	0010	–X M2 OVC	1 1/2		F				27	15		977	
SA	0055	–X M2 OVC	1 1/2		F		74	74	25	10		977	
SP	0120	W2X	1/2		F				25	10		979	
SA	0155	W2X	1/2		F		74	74	25	10		980	R23VR24
SA	0255	W2X	1/2		F		74	74	27	10		980	R23VR40
SA	0355	W2X	1/2		F		74	74	27	10		980	R23VR45
SA	0455	30 SCT E80 OVC	2		FH		71	71	00	00		982	
SA	0555	–X E80 BKN	2		FH		70	70	00	00		985	
SA	0655	–X 80 SCT E150 BKN	2 1/2		FH		71	71	00	00		988	
SP	0724	80 SCT E150 BKN	5		FH				00	00		991	VSBY S-W 2 1/2
SA	0755	E150 BKN	8				74	72	00	00		991	VSBY S-W 5

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY

Figure A36. Surface Weather Observations Taken at the FAA Tower at Otis AFB

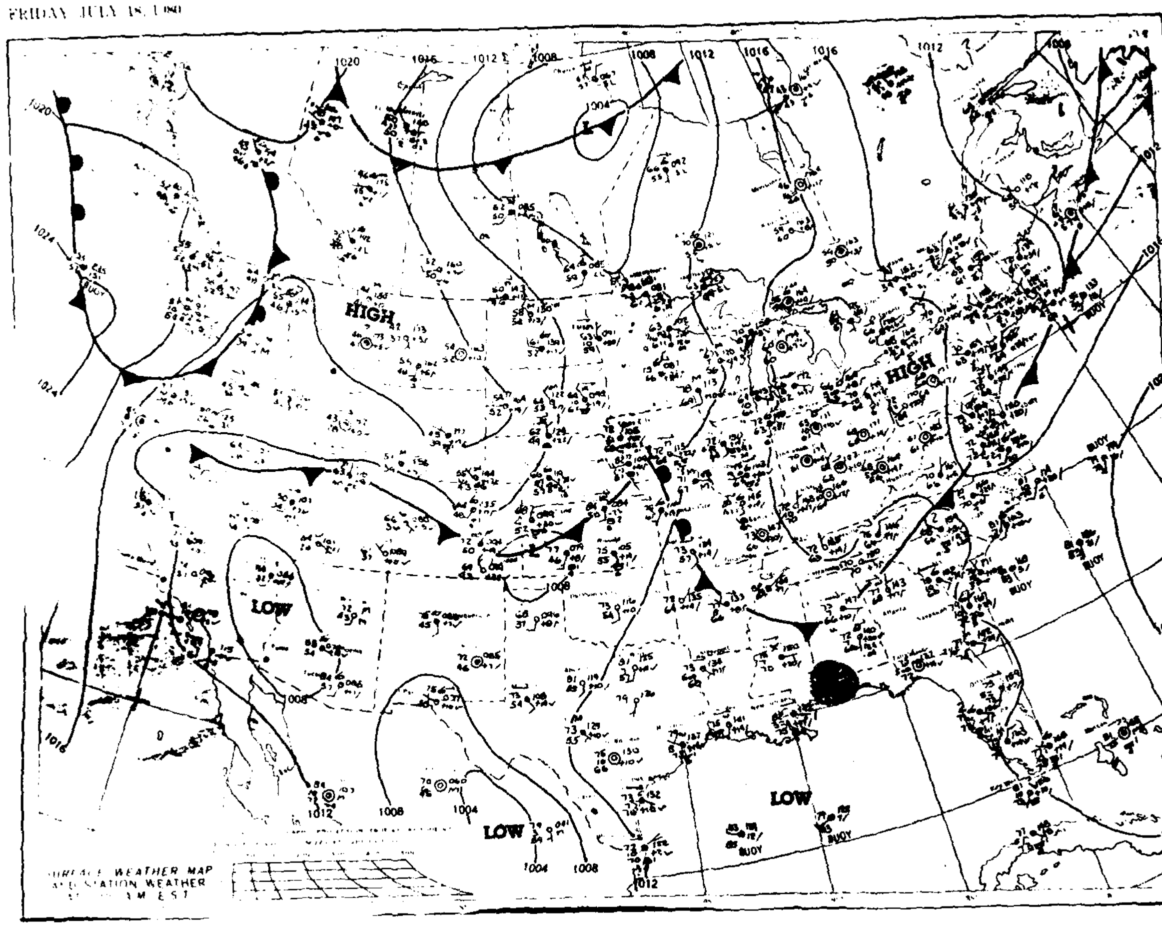


Figure A37. Surface Weather Map for 0800 EDT on 18 July 1980

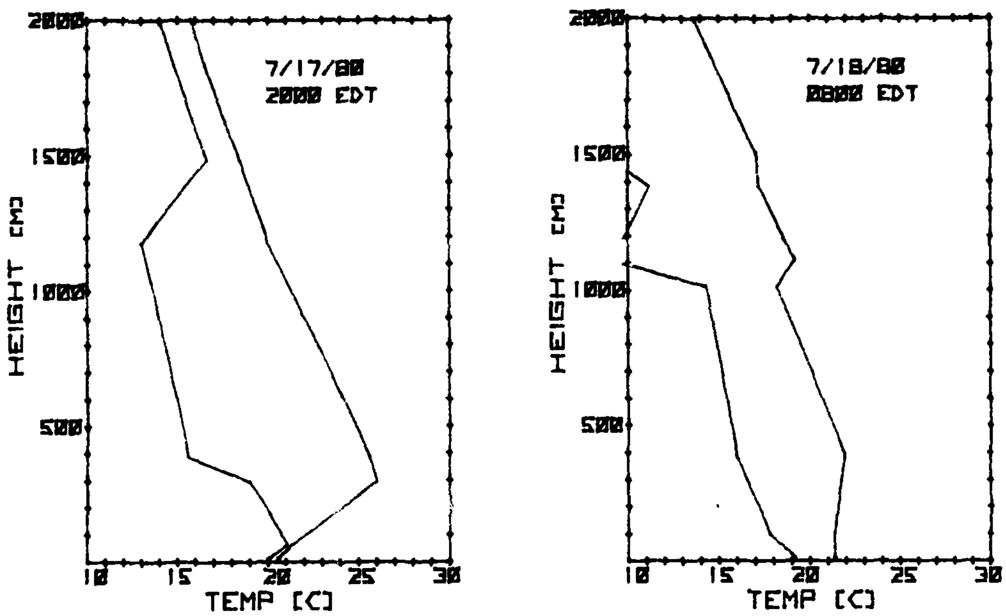


Figure A38. Chatham Radiosonde Soundings Before and After the Fog Episode

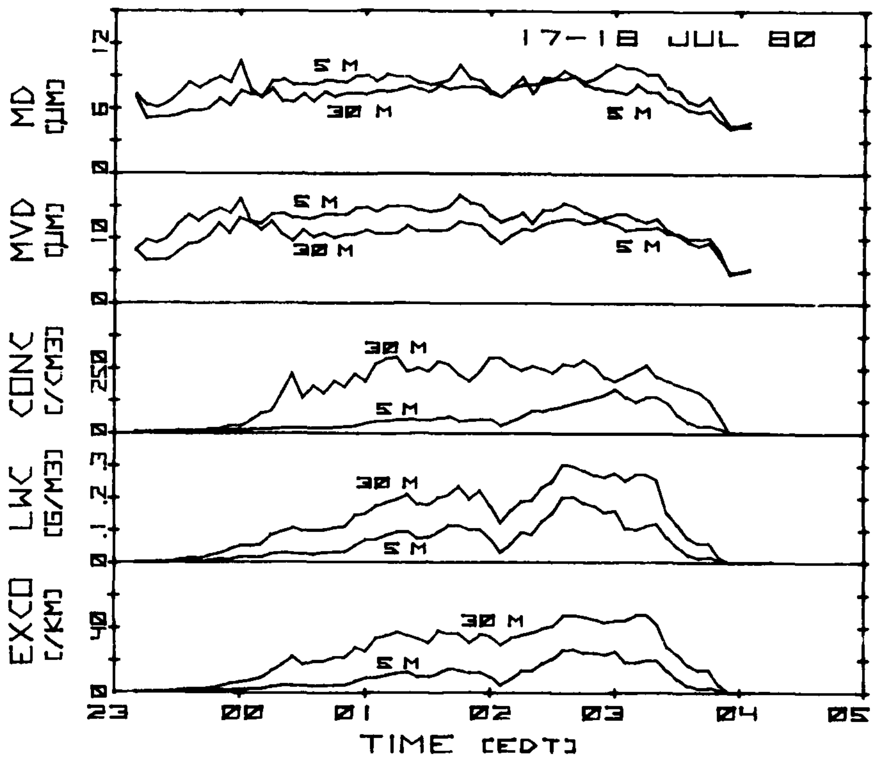


Figure A39. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

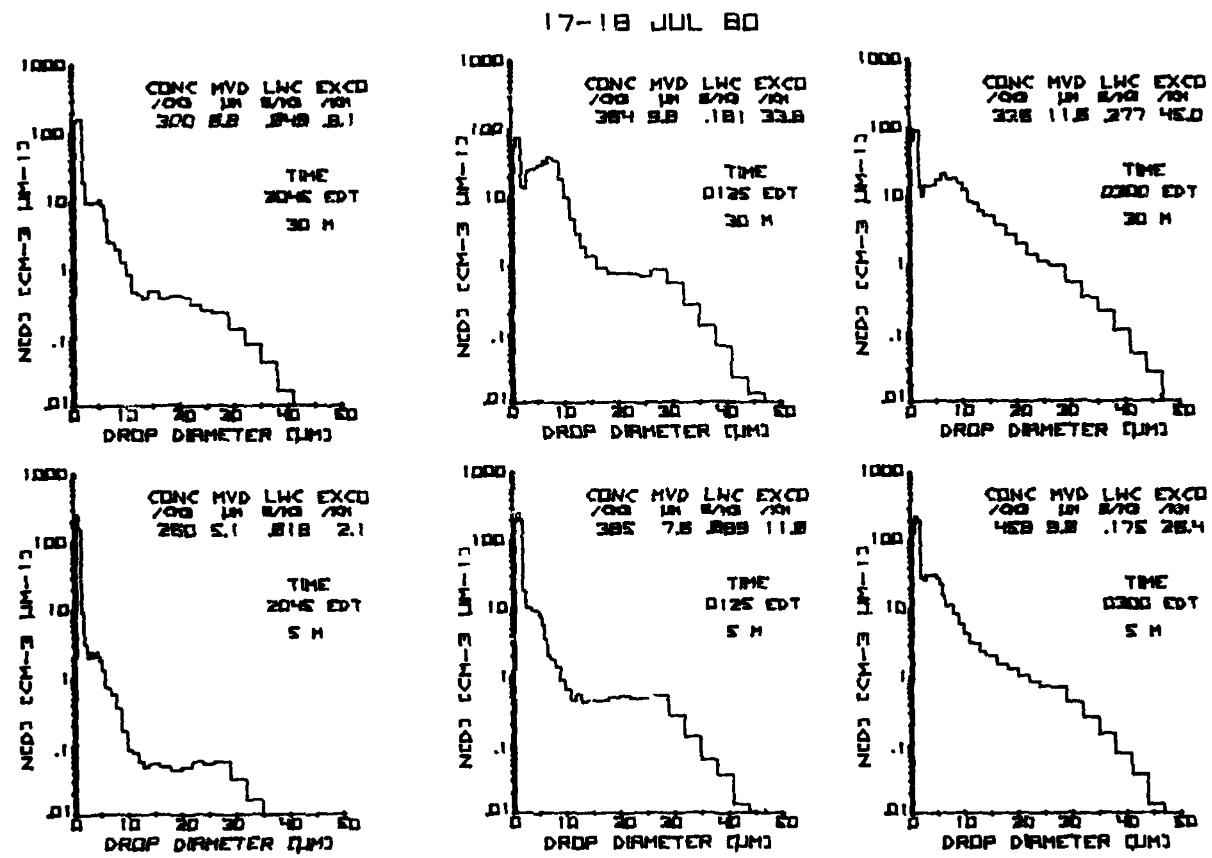


Figure A40. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

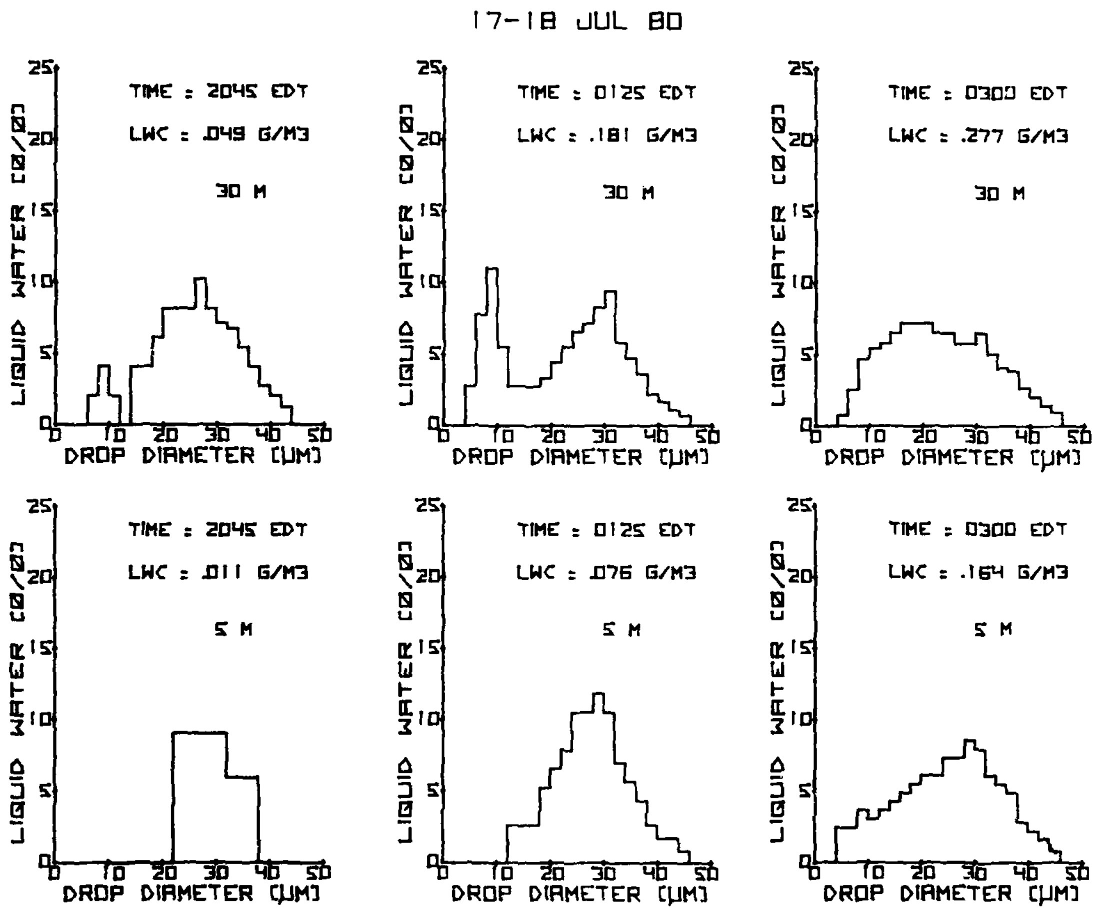


Figure A41. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

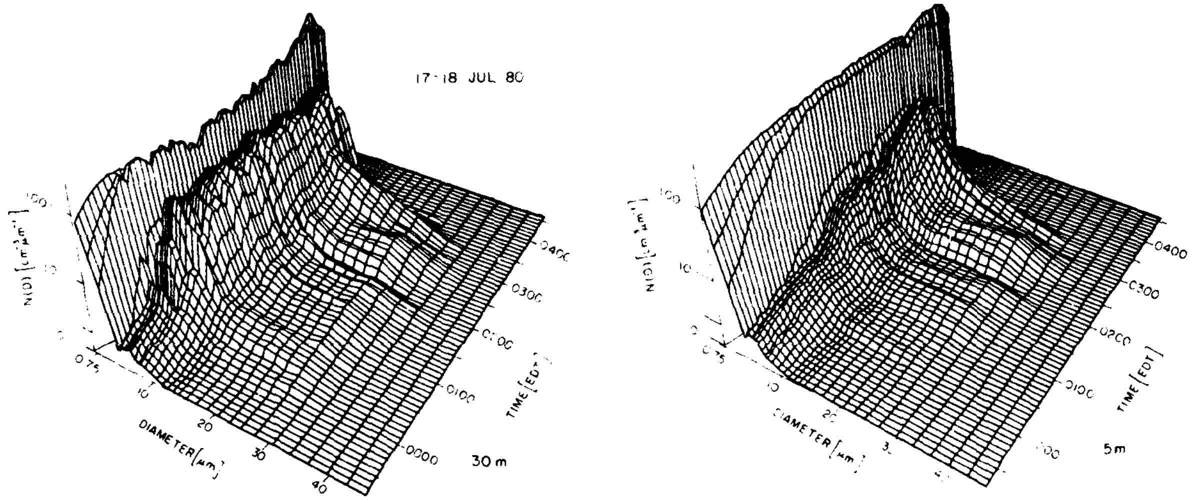


Figure A42. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

Case 7: 28-29 July 1980
(see Figures A43 through A49)

Time Period (vis < 1 mi)	0400-0535 EDT
Duration	1 h 35 min
Wind Direction	130°
Wind Speed	4 knots
Temperature	69°F
Estimated Depth	120 m
Comments	Fog occurred on east winds due to high pressure to the east and low pressure to the southwest. Fog preceded by stratus. Fog lifted shortly after sunrise. Stratus became broken by 0900.

SURFACE WEATHER OBSERVATIONS

OTIS TOWER
7/29/80

Time in Column 2 is GMT ___ LDT X

TYPE (1)	TIME (2)	SKY AND CEILING (Hundreds of feet) (3)	VISIBILITY (miles) SURFACE (4)	TOWER (4a)	WEATHER AND OBSTRUCTIONS TO VISION (5)	SEA LEVEL PRESS (mb) (6)	TEMP (°F) (7)	DEW PT. (°F) (8)	WIND DIRECTION (9)	WIND SPEED (Kts) (10)	CHARACTER (11)	ALTIM. SETTING (ins.) (12)	REMARKS AND SUPPLEMENTAL
SA	2355	20 SCT	14				72	70	13	04		007	
SA	0055	20 SCT	7				72	64	00	00		006	
SA	0155	−X	3		F		70	69	00	00		004	
SA	0255	−X	3		F		70	69	00	00		004	
SP	0310	M12 BKN	3		F				00	00		004	
SA	0355	M12 OVC	3		F		70	68	00	00		000	
SP	0425	M2 OVC	1/2		F				12	04		999	
SA	0455	M1 OVC	1/4		F		69	69	13	04		998	
SA	0555	M3 OVC	2		F		70	70	12	06		998	
SA	0655	M3 OVC	5		F		71	71	13	04		998	
SA	0755	M4 OVC	5		F		72	71	14	10		997	
SA	0855	M6 BKN 120 OVC	7				74	72	13	05		997	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY (Midnight to Midnight)

Figure A43. Surface Weather Observations Taken at the FAA Tower at Otis AFB

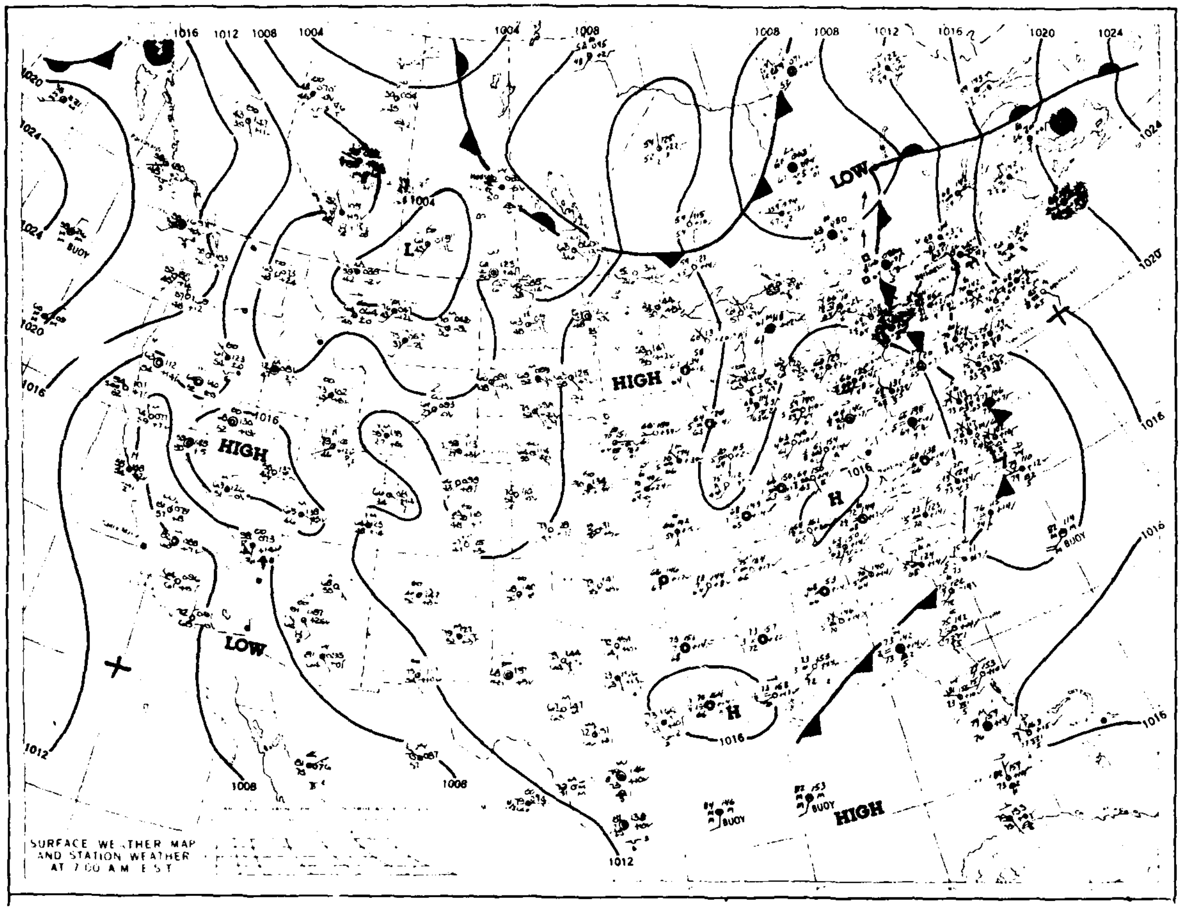


Figure A44. Surface Weather Map for 0800 EDT on 29 July 1980

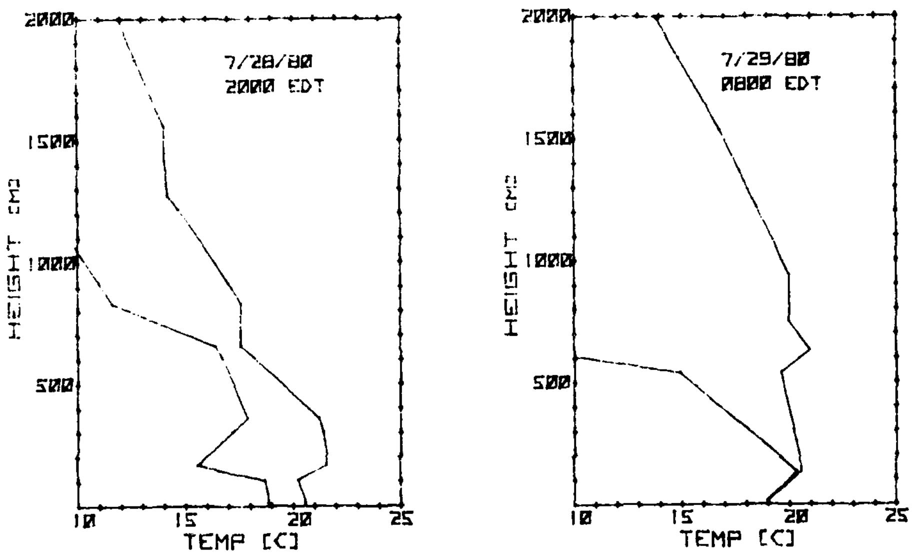


Figure A45. Chatham Radiosonde Soundings Before and After the Fog Episode

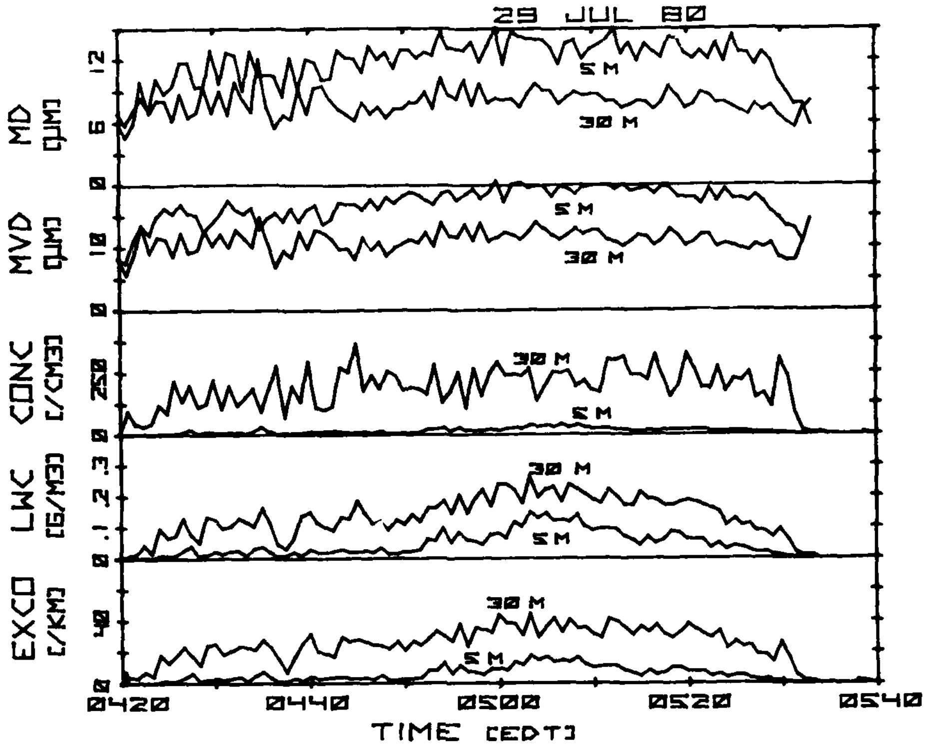


Figure A46. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-µm diameter

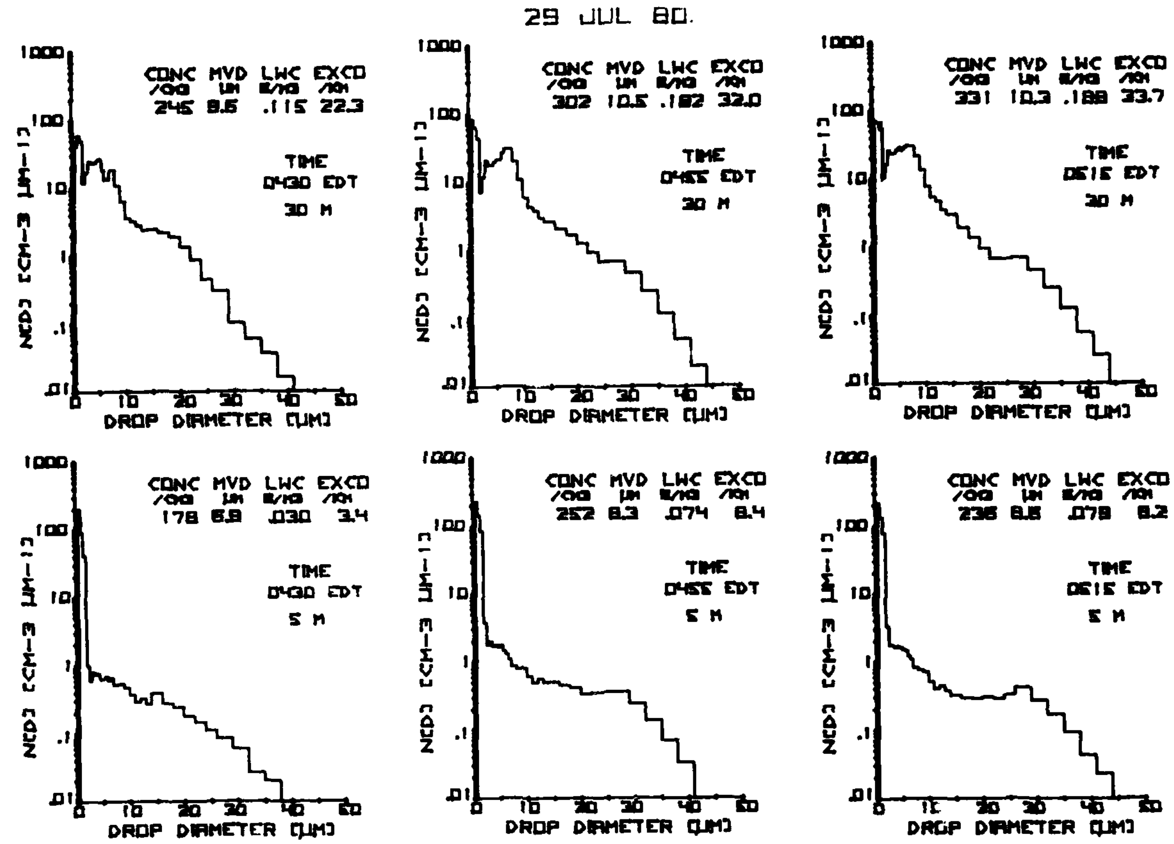


Figure A47. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

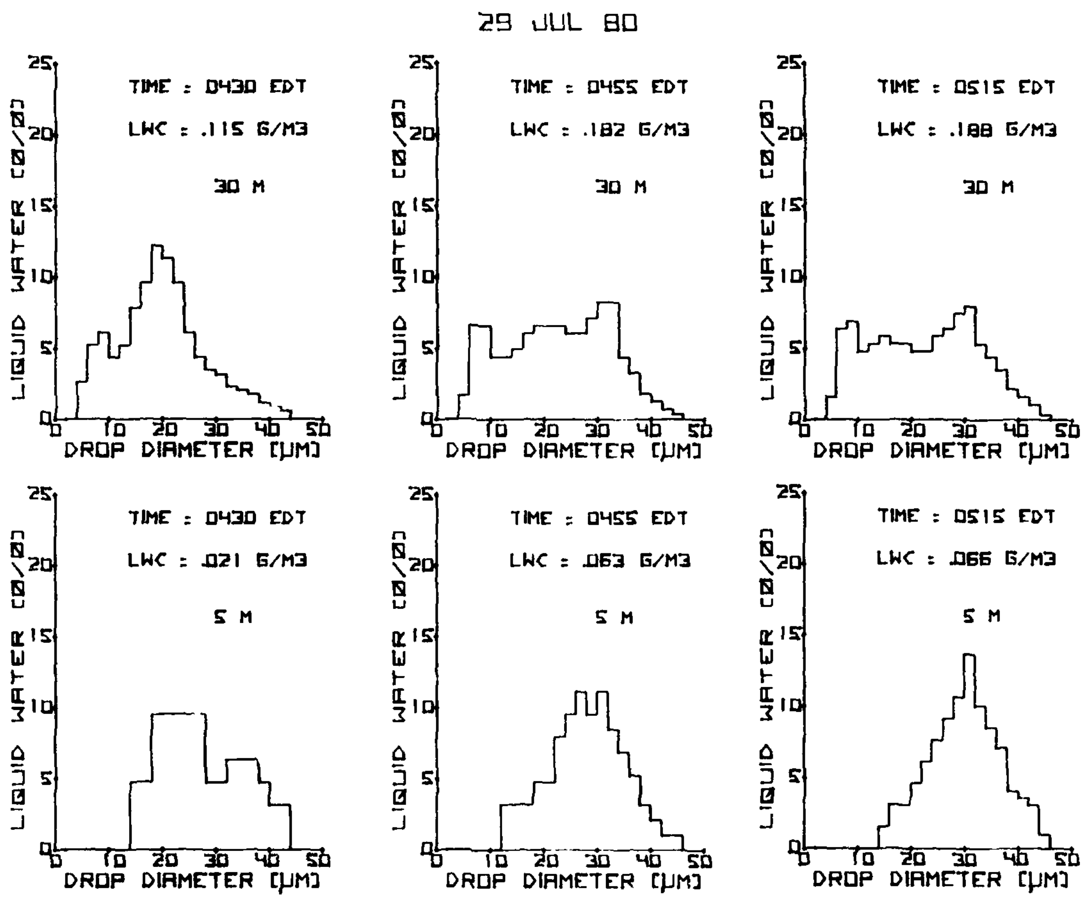


Figure A48. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

AD-A119 928 AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA F/G 4/2
MICROPHYSICAL PROPERTIES OF FOG AT OTIS AIR FORCE BASE.(U)
JAN 82 B A KUNKEL
UNCLASSIFIED AFGL-TR-82-0026 NL

2 of 2

END
DATE
FILMED
11 82
DTIC

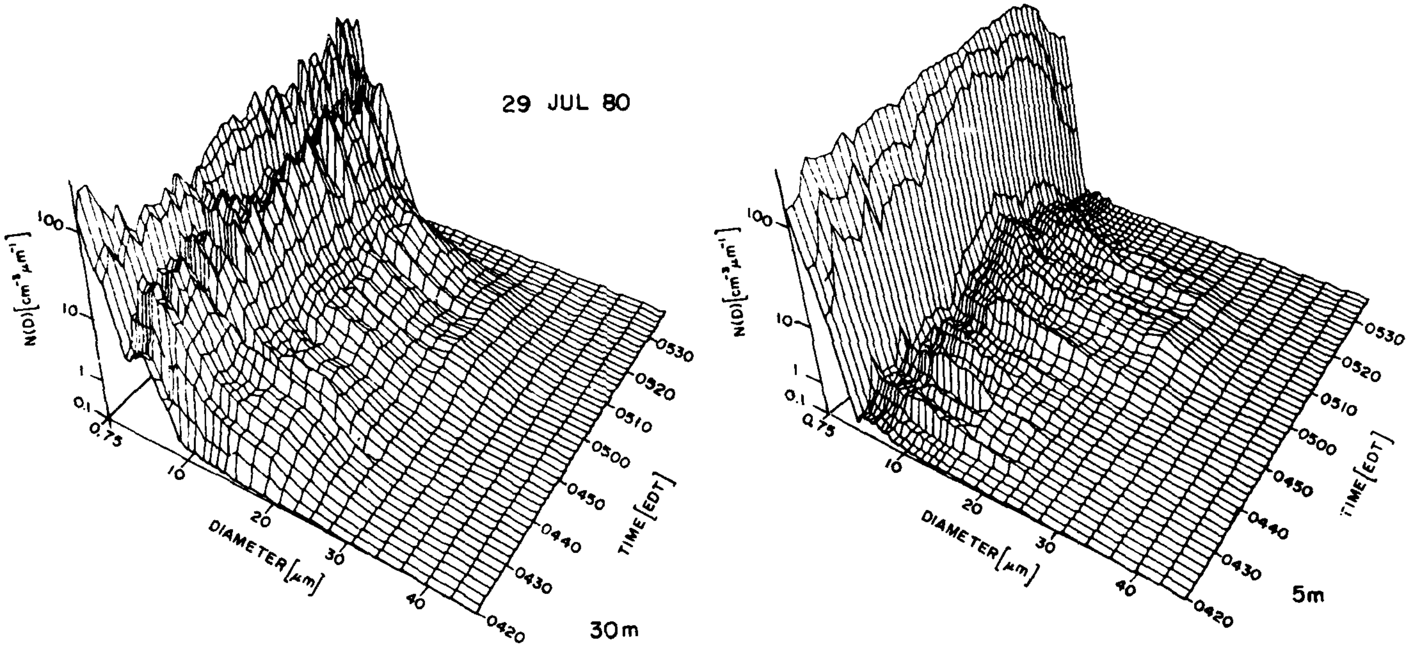


Figure A49. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

Case 8: 29-30 July 1980
(see Figures A50 through A56)

Time Period (vis < 1 mi)	0000-0050 EDT
Duration	50 min
Wind Direction	230°
Wind Speed	2 knots
Temperature	75°F
Estimated Depth	Unknown
Comments	Fog preceded by low stratus, showers. and drizzle. Saturated layer extends up to 1800 m. Cold front passed site at 0130.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SURFACE WEATHER OBSERVATIONS

Time in Column 2 is: GMT ____ LDT X

OTIS TOWER
7/29-30/80

Type (1)	Time (2)	Sky and Ceiling (3)	Visibility Surface (4)	Visibility Tower (4a)	Weather and Obstructions to Vision (5)	Sea Level Press. (6)	Temp (7)	Dew Pt (8)	Wind Direction (9)	Wind Speed (10)	Wind Character (11)	Altim. Setting (12)	Remarks and Supplemental (13)
SA	1755	M4 OVC	5		RW-F		75	75	13	06		982	
SP	1840	M4 OVC	3		F				17	06		981	
SA	1855	M4 OVC	3		L-F		76	73	18	06		980	
SP	1930	M2 BKN 4 OVC	3		L-F				17	10		980	
SA	1955	M2 BKN 3 OVC	2		F		76	76	17	12		979	
SP	2055	M2 OVC	3		F		75	75	17	10		978	
SA	2155	M3 OVC	3		F		75	75	18	10		978	
SA	2255	M3 OVC	3		F		75	75	18	05		976	
SA	2355	M2 OVC	1		F		75	75	00	00		975	
SA	0055	M2 OVC	1		F		75	75	00	00		975	
SA	0155	M1 OVC	1		F		74	74	00	00		974	
SA	0255	M2 OVC	1		F		71	71	34	08		975	
SA	0355	M2 SCT 10 OVC	1 1/2		F		71	71	32	06		977	
SP	0410	M4 BKN 10 OVC	10						34	05		979	
SA	0455	4 SCT M16 BKN 25 BKN	20				70	69	33	05		980	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY (Midnight to Midnight)

Figure A50. Surface Weather Observations Taken at the FAA Tower at Otis AFB

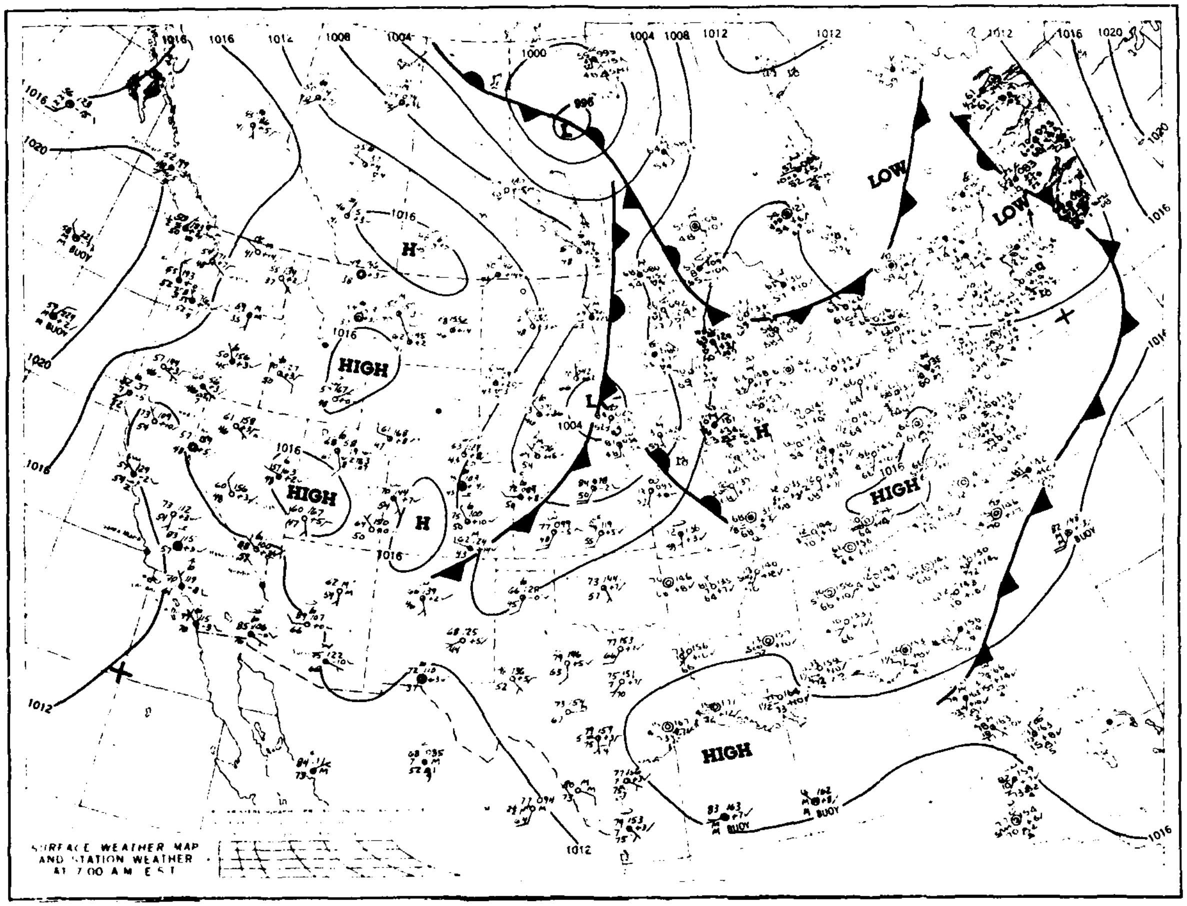


Figure A51. Surface Weather Map for 0800 EDT on 30 July 1980

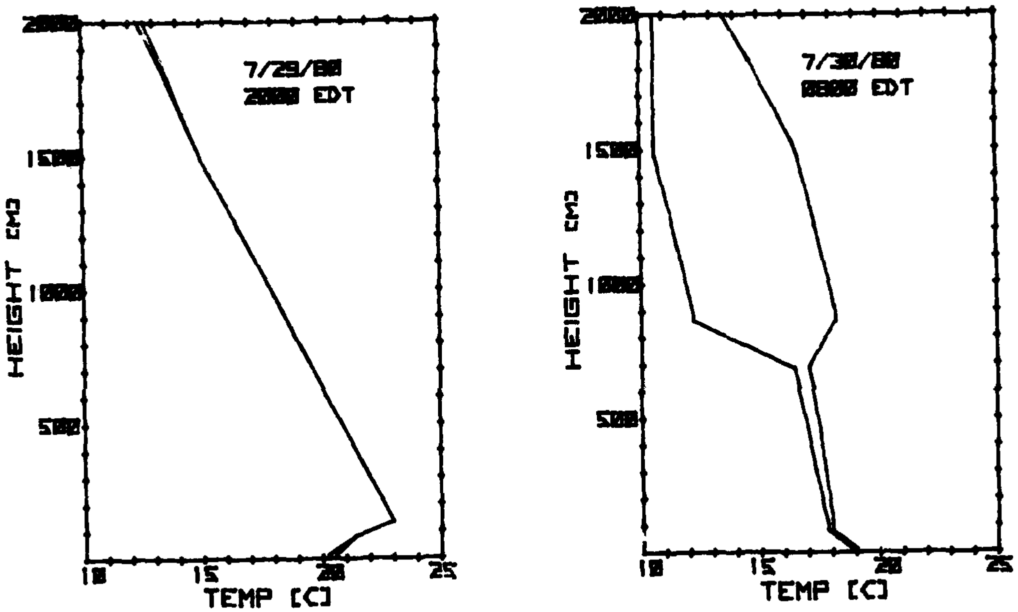


Figure A52. Chatham Radiosonde Soundings Before and After the Fog Episode

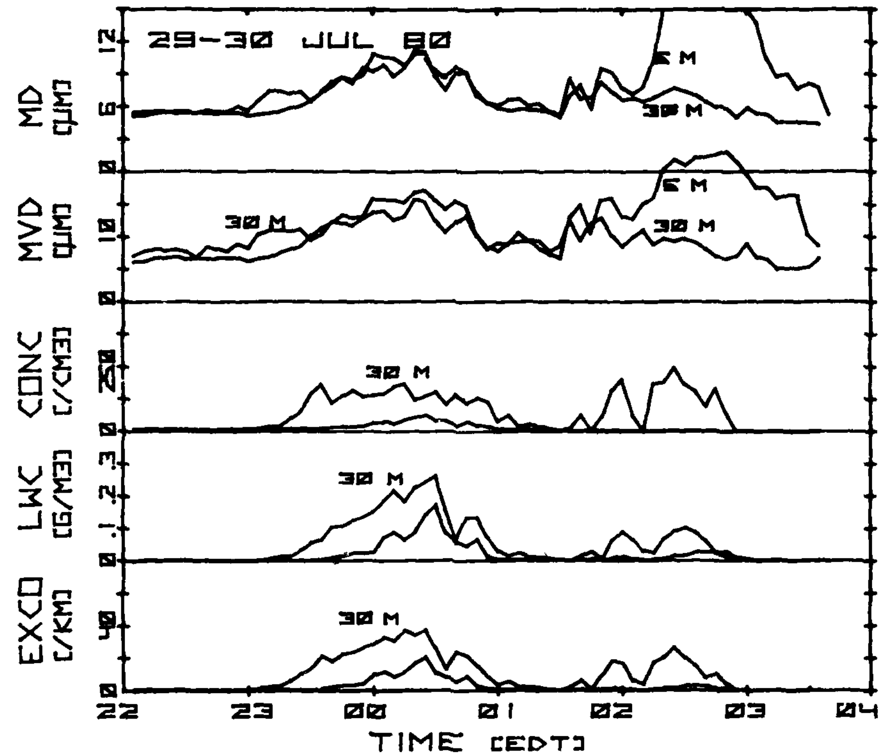


Figure A53. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

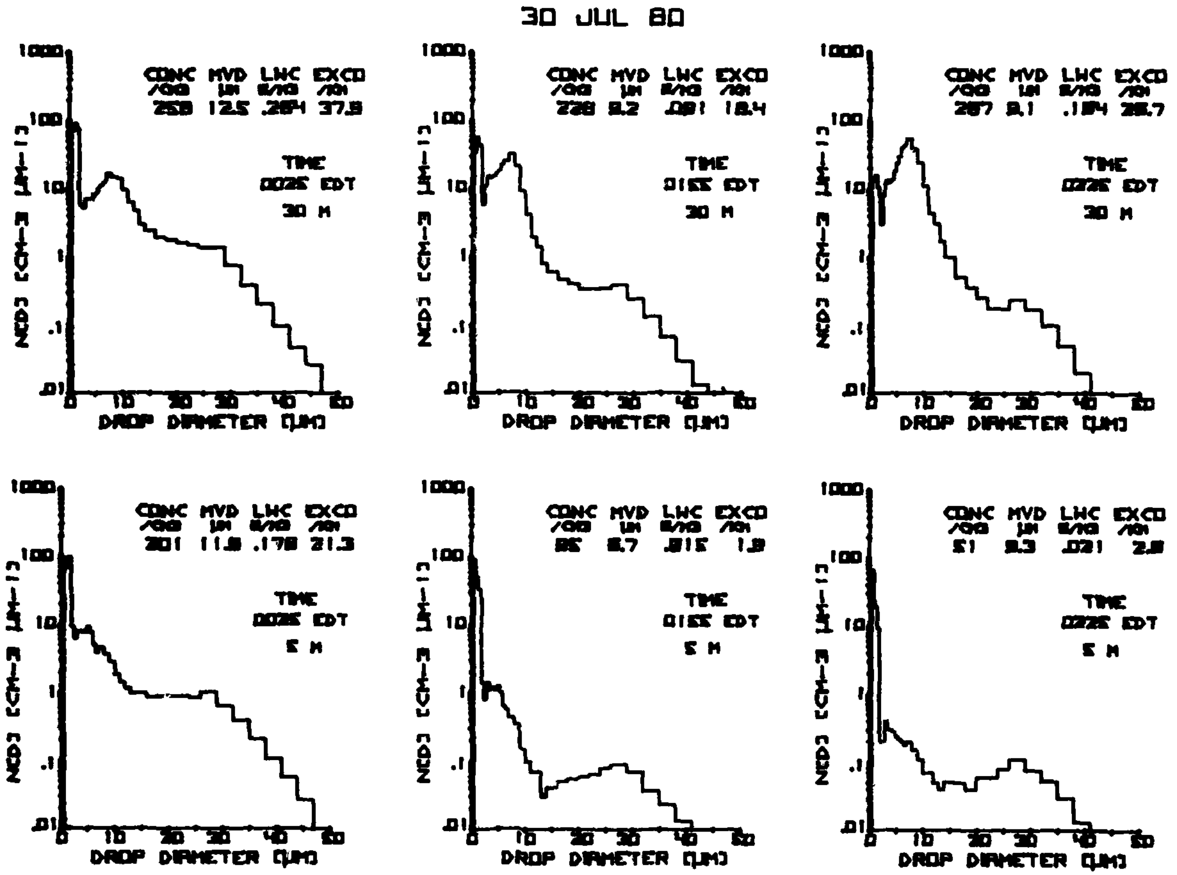


Figure A54. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

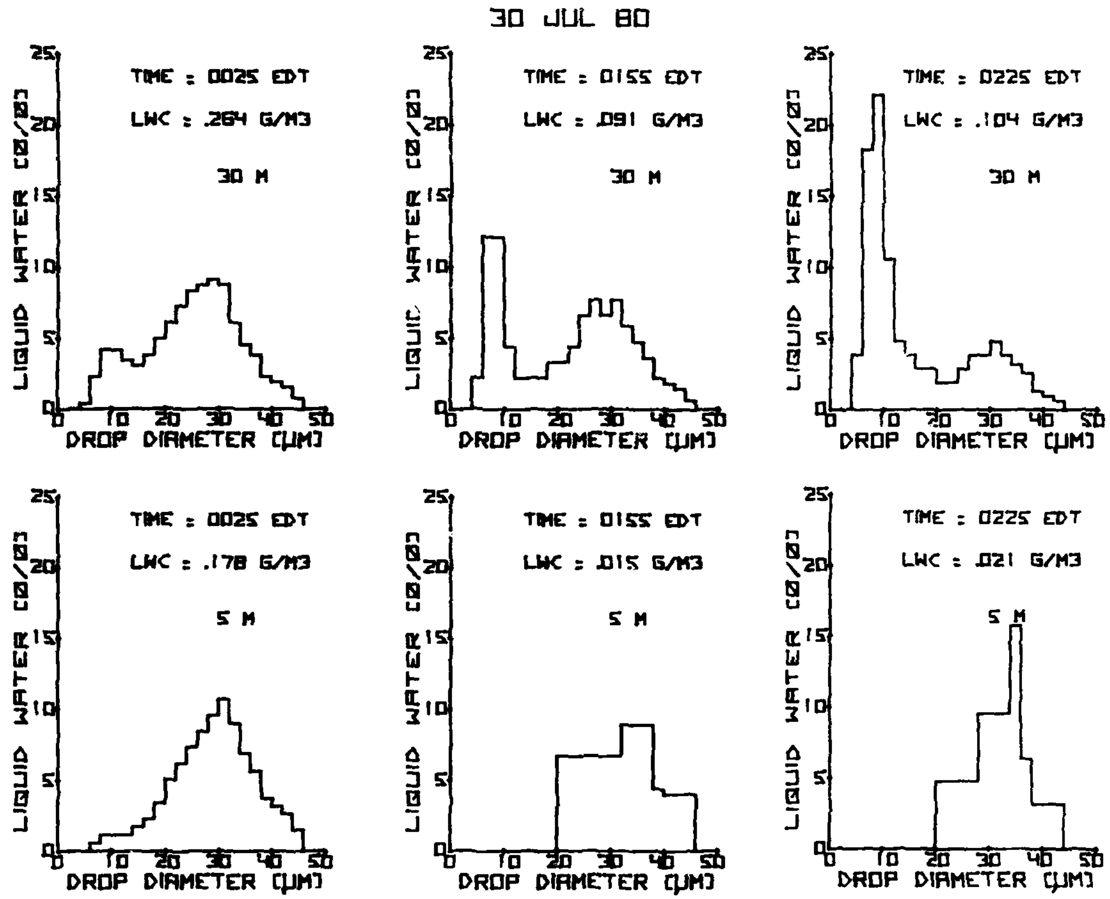


Figure A55. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

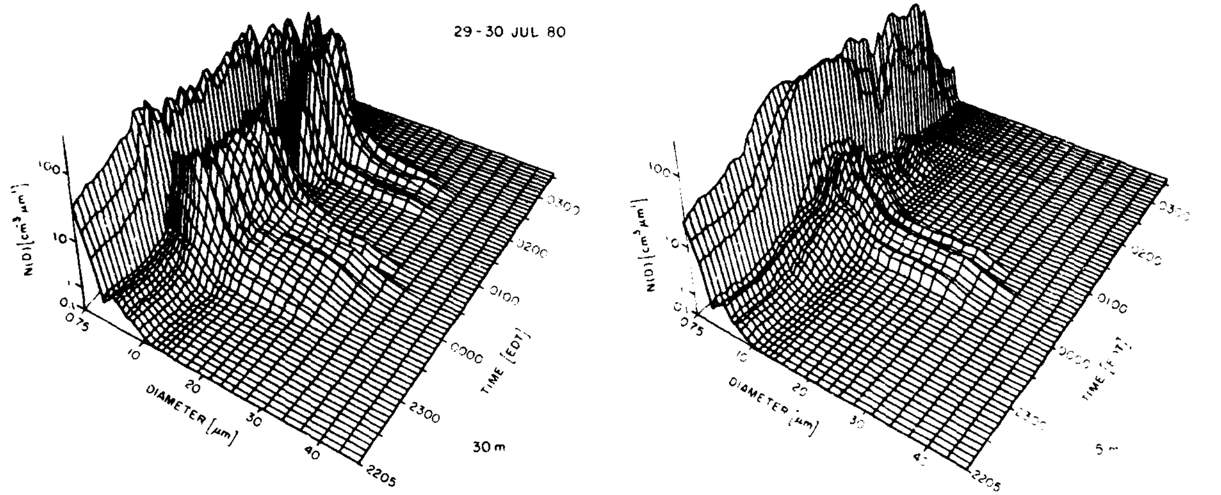


Figure A56. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

Case 9: 5-6 August 1980
(see Figures A57 through A63)

Time Period (vis < 1 mi)	2130-2200 EDT
Duration	1 h 45 min
Wind Direction	240°
Wind Speed	6 knots
Temperature	78°F
Estimated Depth	350-500 m
Comments	Fog preceded by low stratus, which persisted throughout the night. Stratus lowered to ground only occasionally. Stratus broke up about 0945.

SURFACE WEATHER OBSERVATIONS

OTIS TOWER
8/5-6/80

Time in Column 2 is: GMT____ LDT__X

Type	Time	Sky and Ceiling	Visibility Surface	Visibility Tower	Weather and Obstructions to Vision	Sea Level Press	Temp	Dew Pt	Wind Direction	Wind Speed	Wind Character	Altim Setting	Remarks
SP	1908	−X E5 BKN	2		FH				19	10		006	
SA	1955	−X M5 OVC	1 1/2		FH		79	78	18	08		005	
SP	2020	−X M5 OVC	1		FH				22	06		006	
SA	2055	W2X	1		FH		78	78	22	06		007	
SA	2155	W1X	3/4		F		78	78	22	06		007	R23VR45
SA	2255	W2X	3/4		F		78	78	23	06		007	R23VR40
SA	2355	W2X	1		F		78	78	24	06		008	
SP	0020	M8 OVC	1 1/2		F				24	06		008	
SA	0055	M8 OVC	2		F		78	78	23	06		008	
SA	0155	M6 OVC	2		F		78	78	24	08		007	
SP	0214	W3X	3/4		F				23	06		007	R23VR40
SA	0255	W1X	1/2		F		78	78	25	06		006	R23VR18
SA	0355	W1X	1/2		F		78	78	24	08		006	R23VR38
SA	0455	W2X	1/2		F		78	78	24	06		006	R23VR34
SA	0555	W4X	1/2		F		79	78	25	06		006	R23VR32
SP	0633	M4 BKN 12 OVC	1		F		79	78	25	06		006	
SP	0655	−X M4 OVC	1		F		79	78	26	06		007	
SP	0730	W3X	1/2		F				25	15		008	
SP	0745	W2X	1		F				25	15		008	
SA	0755	W4X	1		F		79	78	25	12		008	
SA	0820	W3X	1/2		F				25	12		007	R23VR50
SA	0855	−X 174 OVC	12		F		80	79	25	12		008	
SP	0945	−X 5 SCT E100 BKN	3		F				25	12		009	

STATION PRESSURE COMPUTATIONS

SUMMARY OF DAY (Midnight to Midnight)

Figure A57. Surface Weather Observations Taken at the FAA Tower at Otis AFB

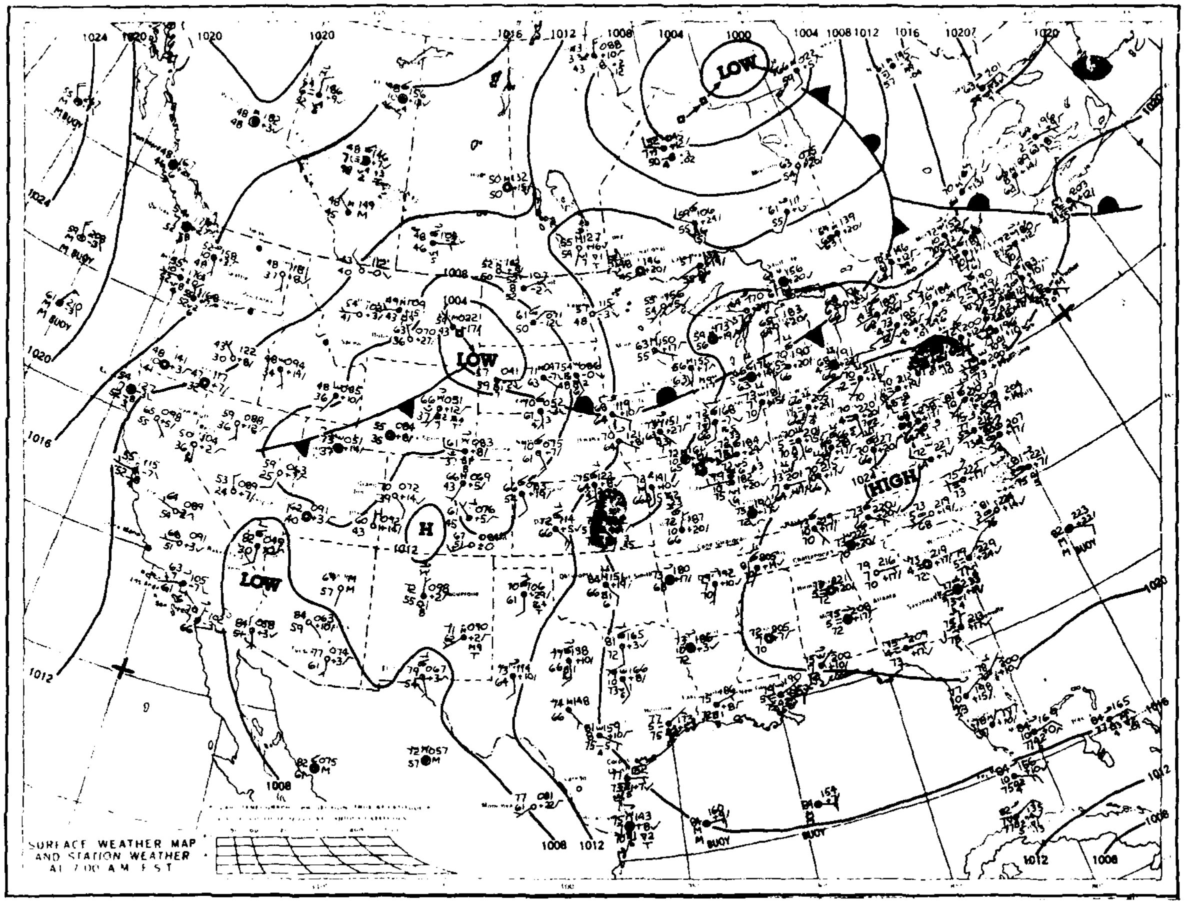


Figure A58. Surface Weather Map for 0800 EDT on 6 August 1980

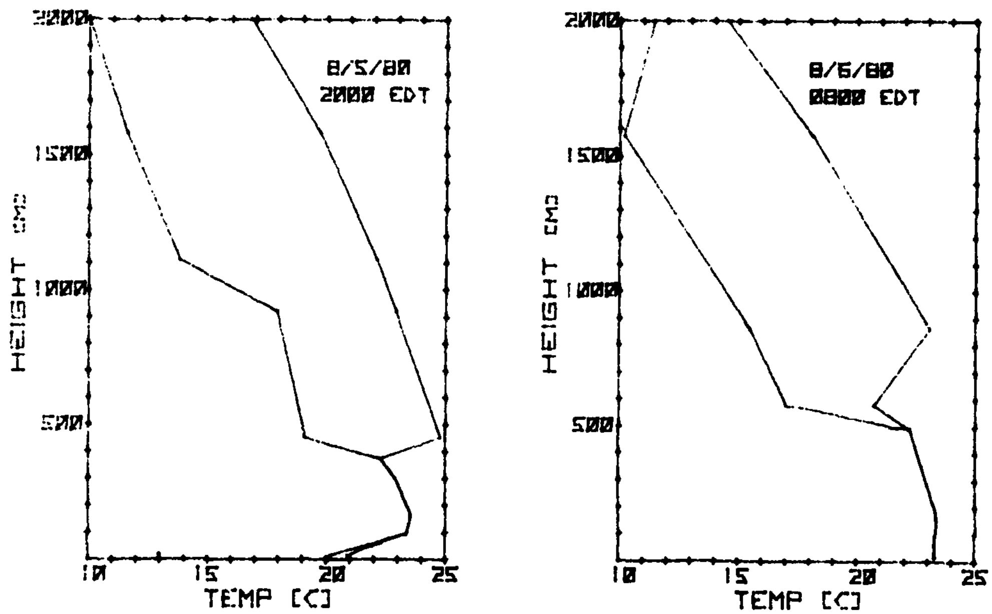


Figure A59. Chatham Radiosonde Soundings Before and After the Fog Episode

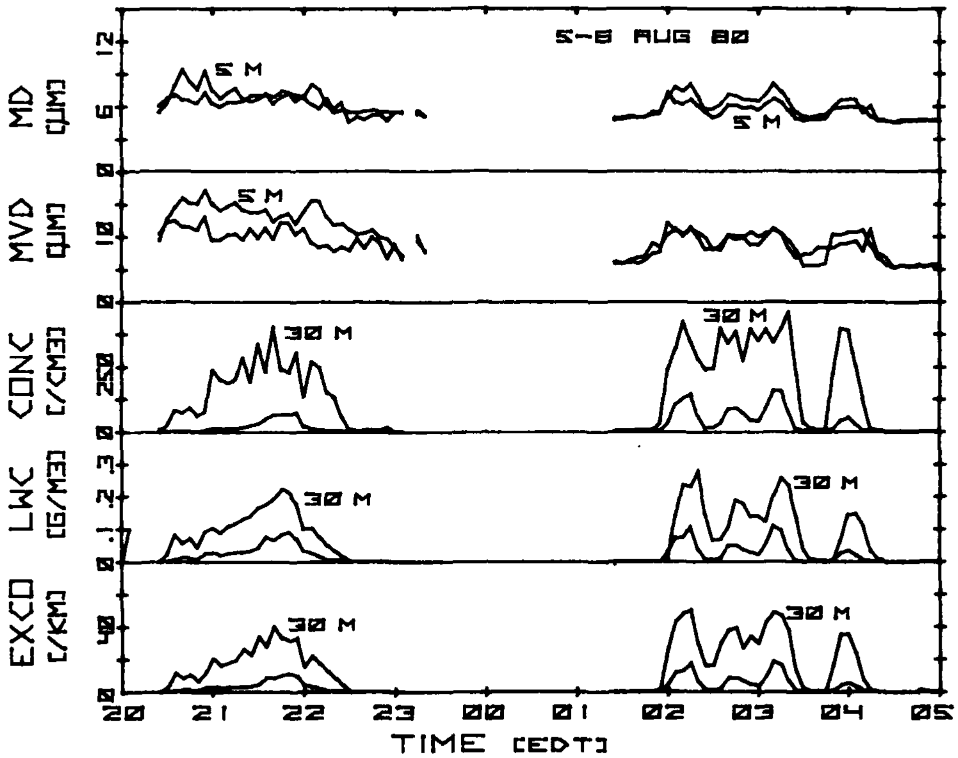


Figure A60. The Temporal Variability of the Fog Microphysical Parameters. Data apply to all fog droplets between 2.5- and 47-μm diameter

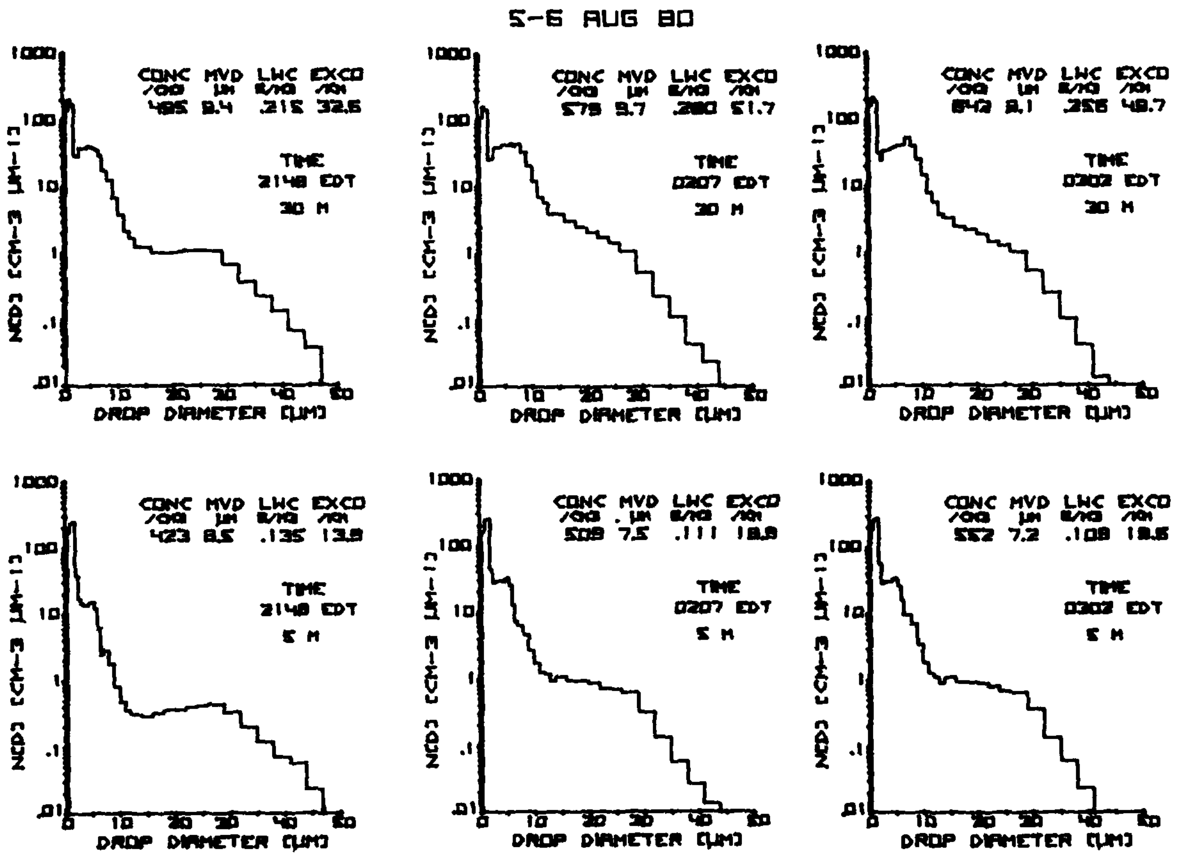


Figure A61. Time Sequence of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

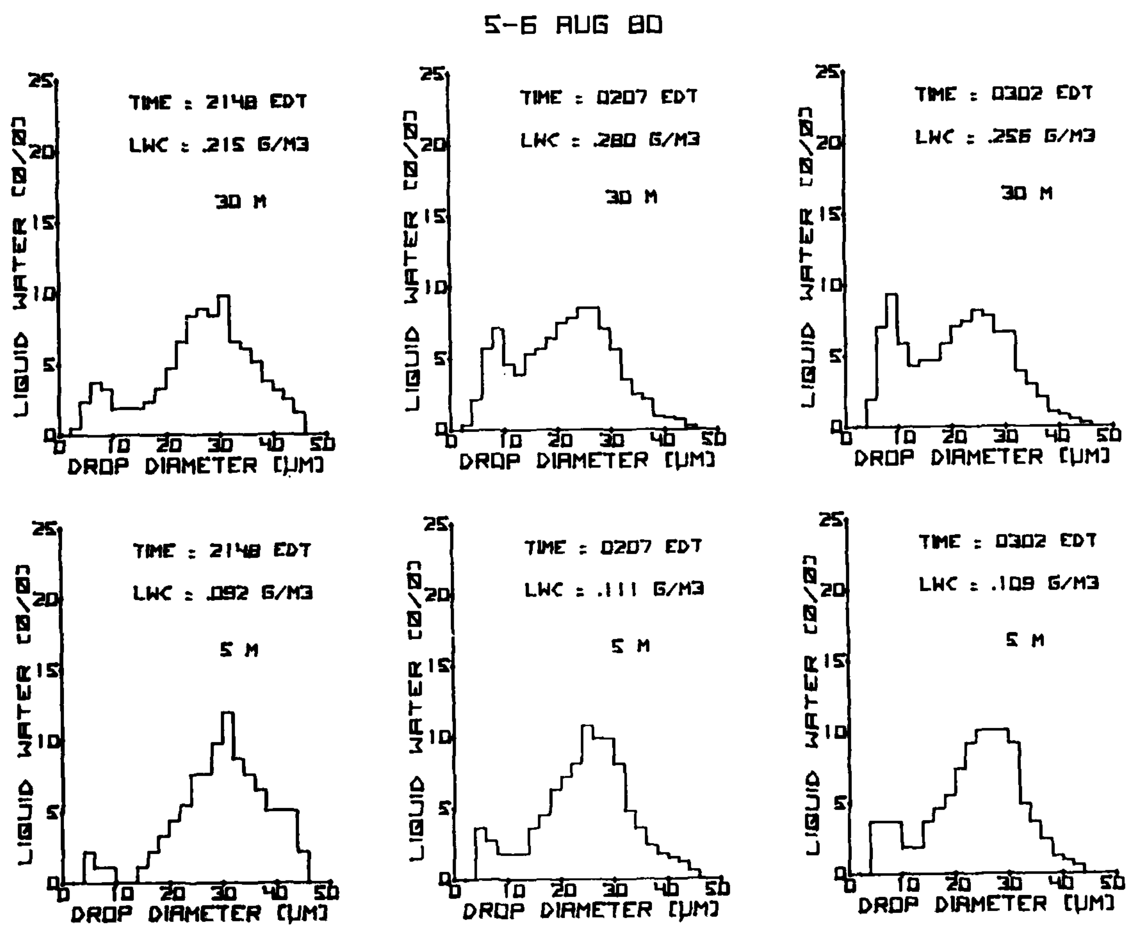


Figure A62. Time Sequence of the Liquid Water Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

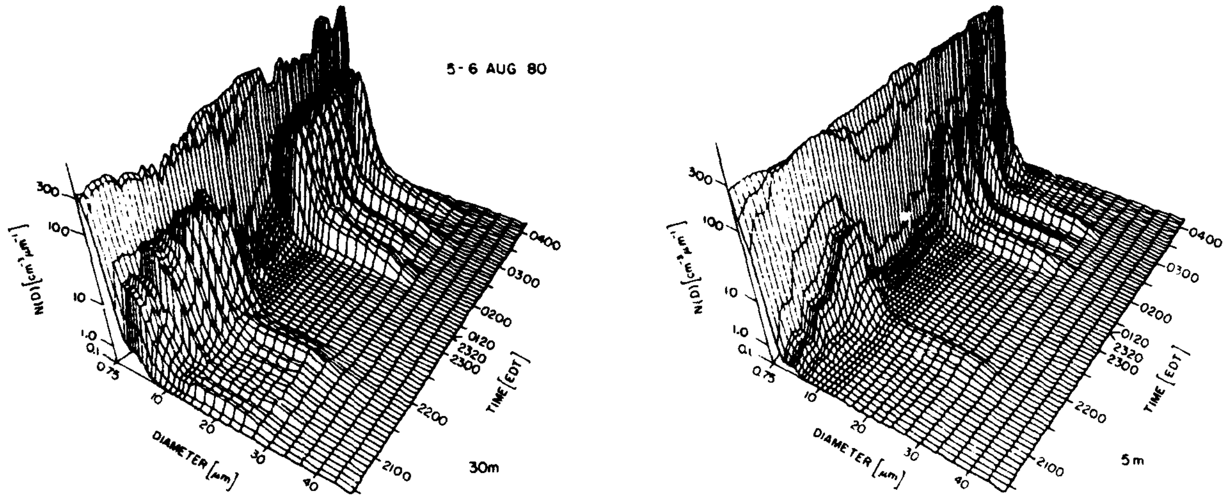


Figure A63. Three-Dimensional Time Plot of the Droplet Spectra Between 0.5 and 47 μm at the 5-m and 30-m Levels

DATE
FILMED

8